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THE MINERAL CONTENT OF TIMOTHY HAY AND OAT STRAW AS FED IN EASTERN CANADA[1]

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At a meeting of the executive of the Eastern Section of the Canadian Society of Animal Production in the fall of 1936, a discussion centred around the mineral content of home-grown live stock feeds, with particular reference to observed deficiencies in these minerals in certain localities. It was felt that the problem was deserving of further study and Dr. Archibald suggested that the Dominion Experimental Farms would undertake investigations in this connection. The purpose of this paper is to report the progress which has been made in preliminary investigations to date.

The ground work for the study was laid at the Central Experimental Farm, Ottawa, at a meeting of several of the Divisions concerned, when it was decided to collect samples of oat straw and timothy hay from farms at a number of points throughout Eastern Canada and have them analyzed to determine their mineral content. It was felt that if analyses of these two widely grown crops showed any marked deficiencies in mineral content, it would be a fairly reliable indication of any general deficiency in calcium and phosphorus which might exist in soils, and also in other crops in a particular district, and that this might be related to mineral deficiencies in the live stock of the district.

The Dominion Experimental Farms and Illustration Stations located as they are throughout Eastern Canada, in representative agricultural districts, provided a convenient means of obtaining samples for analysis. Samples of oat straw were received from 111 Illustration Stations and eight Experimental Farms and of timothy hay from 114 Illustration Stations and nine Experimental Farms.

INFORMATION FROM QUESTIONNAIRES

The chemical data obtained from the analyses of these samples was supplemented by information from questionnaires in regard to feeding practices, evidence of mineral deficiency, type of soil, and fertilizer treatments. In reply to the question: "Have you noticed any evidence of mineral deficiency in the forage crops fed to your cattle, as indicated by their chewing bones, wood, leather, iron or earth, particularly in the spring

[1] An address delivered before the Eighth Annual General Meeting of the Canadian Society of Animal Production (Eastern Section) at the Central Experimental Farm, Ottawa, Ont., on June 16, 1937.

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and early summer months", 69 operators of Illustration Stations reported that such evidence existed while 38 had noticed no deficiency. This alone is evidence of the prevalence of mineral deficiencies.

In regard to feeding practices, in 100 replies the average amount of hay fed was 19.9 pounds per day. Eighty-six co-operators fed roots at an average rate of 25.4 pounds per day. Comparatively few fed silage, 12 only reporting, and the average amount fed was 23.2 pounds per day. Twenty-six fed oat straw to their cattle at an average rate of 11.2 pounds per day. Eighty reported that they were feeding grain or a meal mixture and 35 that no meal was being fed. The average rate of feeding meal was 4.9 pounds per day. In reply to the question, "Are you including or have you ever included in your grain mixture any mineral supplements such as bone meal, fish meal or lime?" 27 replied in the affirmative and 13 had not supplied such supplements. Where mineral supplements had been fed 22 reported beneficial results, while four could see no improvement.

In an attempt to correlate soil type with mineral deficiency it was found that 60% of those whose farms were located on clay and clay loam soils had experienced some indication of mineral deficiency. On the lighter soils and on muck soils the percentage was higher, there being 79% on sandy loam soils, 88% on gravelly loam and 80% on the highly organic muck soils which are relatively low in minerals.

On Experimental Farms a slightly different condition exists than that which prevails on the Illustration Stations. Nine Experimental Farms sent in reports to questionnaires and at all of the Farms with the exception of Charlottetown, P.E.I., mineral supplements were fed to the live stock. The result was that only one farm reported any evidence of mineral deficiency and this was at Lennoxville in the Eastern Townships of Quebec. Hay, roots or silage, and meal were fed in fairly liberal amounts at all Experimental Farms.

CHEMICAL ANALYSES OF OAT STRAW AND TIMOTHY HAY

All of the samples of oat straw and timothy hay from Experimental Farms and Illustration Stations were analysed to determine the percentage of calcium and phosphorus which they contained. Table 1 lists the number of samples from each of the geographical districts.

Naturally considerable variation is expected in samples secured more or less at random from the mows of farms in widely separated localities. Many factors unite to make the correlation of results very difficult. Crops are harvested under variable climatic conditions some of which favour the satisfactory curing of the crop while others produce varying degrees of weathering. The crops, particularly the timothy, are cut at different stages of maturity which effects the chemical composition considerably. The chemical nature of the leaf of the plant is different from that of the stemmy portions and where difficulties in harvesting present themselves, very often a large number of leaves are lost. In the case of timothy hay, it is very difficult to obtain it free from clover, as a mixture of clover and timothy seed is usually sown. The presence of clover increases the mineral content, particularly the calcium, quite markedly.

With a view to eliminating as many of these factors as possible, a botanical examination was made of the samples by Mr. W. G. Dore of

TABLE 1.—NUMBER OF SAMPLES OF OAT STRAW AND TIMOTHY HAY RECEIVED FROM VARIOUS DISTRICTS IN EASTERN CANADA

Province or District	Station	Oat straw No. of samples	Timothy hay No. of samples
Prince Edward Island	Illustration Station	14	14
	Experimental Station	1	1
Nova Scotia	Illustration Station	13	13
	Experimental Station	1	2
New Brunswick	Illustration Station	19	18
Eastern Quebec	Illustration Station	18	18
	Experimental Station	2	1
Lake St. John	Illustration Station	3	3
Central Quebec	Illustration Station	11	11
	Experimental Station	2	2
Eastern Ontario and Western Quebec	Illustration Station	15	15
	Experimental Station	1	1
Northern Ontario and Northern Quebec	Illustration Station	18	22
	Experimental Station	1	4
	Total	119	125

the Botanical Division, Central Experimental Farm, Ottawa. In this examination it was possible to determine the percentage of legumes, weeds, and other foreign matter in the samples. Consideration was given to the estimated stage of maturity at which the samples were harvested. Observations were made in regard to weathering which was characterized by the colour of the sample and its general appearance.

From this examination it was determined that 18 of the samples of straw were of poor colour and 21 samples only fair, which indicated a considerable amount of weathering. In the samples of hay 22 were poor in colour and 34 fair. Forty-six samples of hay contained legumes in amounts varying from 5 to 85%.

With these and other observations it was possible to select data which more truly represented comparable samples of the feeds in question. The analyses for oat straw have been affected by weathering and in cases where this was indicated by a high calcium content, the data have not been used. There was not much adulteration of the straw samples by other herbage, but the hay samples often contained a considerable proportion of other grasses, legumes, and weeds. The presence of the legumes would have the greatest effect in altering the composition and where this effect has been appreciable, the data have not been included in the comparison of timothy samples. As with the oat straw, where there were evidences of severe weathering the data were discarded.

The chemical data presented herewith are calculated on a dry matter basis. The percentage of calcium and phosphorus on this basis is only

slightly higher than that contained in the forages as they are normally fed to the live stock; since the moisture content is probably not over 10%, the percentage of the two minerals is low. A summary of the data is presented in Tables 2 and 3 and is an attempt to give maximum, minimum and average figures for normal and normally harvested forages as representative of the districts where they were grown.

TABLE 2.—PERCENTAGE OF CALCIUM AND PHOSPHORUS IN SAMPLES OF OAT STRAW FROM VARIOUS DISTRICTS IN EASTERN CANADA

Locality	No. of samples	Calcium (water-free basis)			Phosphorus (water-free basis)		
		Maximum	Minimum	Average	Maximum	Minimum	Average
		p.c.	p.c.	p.c.	p.c.	p.c.	0.c.
Prince Edward Island							
Illustration Stations	14	0.37	0.17	0.28	0.16	0.03	0.09
Experimental Station (Charlottetown)	1	0.48	0.48	0.48	0.16	0.16	0.16
Nova Scotia							
Illustration Stations	12	0.30	0.20	0.26	0.12	0.04	0.07
Experimental Station (Kentville)	1	0.19	0.19	0.19	0.07	0.07	0.07
New Brunswick							
Illustration Stations	18	0.42	0.17	0.30	0.15	0.03	0.07
Eastern Quebec							
Illustration Stations	16	0.40	0.19	0.31	0.13	0.02	0.07
Experimental Stations (Cap Rouge and Ste. Anne)	2	0.41	0.36	0.39	0.16	0.11	0.14
Lake St. John							
Illustration Stations	1	0.28	0.28	0.28	0.06	0.06	0.06
Central Quebec							
Illustration Stations	11	0.55	0.21	0.35	0.19	0.04	0.10
Experimental Stations (Lennoxville and Farnham)	2	0.39	0.37	0.38	0.17	0.09	0.13
Eastern Ontario and Western Quebec							
Illustration Stations	14	0.53	0.24	0.36	0.13	0.03	0.07
Experimental Stations (L'Assomption)	1	0.26	0.26	0.26	0.07	0.07	0.07
*Northern Ontario and Quebec**							
Illustration Stations	16	0.53	0.18	0.34	0.14	0.02	0.09
Experimental Stations (Kapuskasing)	1	0.29	0.29	0.29	0.07	0.07	0.07

* Including Northwestern Ontario.

DISCUSSION OF RESULTS OF CHEMICAL ANALYSES OF OAT STRAW

Illustration Stations

Calcium

The average percentage of calcium in the samples of oat straw from Illustration Stations in Eastern Canada as presented in Table 2, ranged from 0.26 in Nova Scotia to 0.36 in Eastern Ontario and Western Quebec.

In the standard work of F. B. Morrison published in *Feeds and Feeding* the average calcium content of oat straw is 0.36%. In Nova Scotia only two out of 12 samples were over 0.30%. In Prince Edward Island it was very little higher, the average content being 0.28%. Lake St. John District in Quebec (one sample only) was the same as Prince Edward Island. Farther west a slightly higher percentage was noticed, Eastern Quebec showing an average of 0.31%, while in Central Quebec the average was 0.35%, Eastern Ontario and Western Quebec 0.36% and Northern Ontario and Northern Quebec 0.34%.

In Central Quebec 7 out of 11 samples analysed contained 0.36% or more and were as high as the average of Morrison. In Eastern Ontario and Western Quebec 11 out of 14 samples reached the standard or exceeded it. These districts might, therefore, be considered as producing oat straw of average quality in respect to lime. The samples from other districts of Eastern Canada are below the standard on the average although with the exception of Nova Scotia, certain of the samples from all districts showed a calcium content above 0.36%.

Experimental Farms and Stations

As was the case with the Illustration Stations in Nova Scotia the calcium content of the oat straw from the Experimental Station, Kentville, Nova Scotia, was very low, being 0.19%. Contrary to the figures from Illustration Stations, on the other hand, were those from Charlottetown, P.E.I., with an unusually high calcium content of 0.48%, while the figure for L'Assomption in Western Quebec and Kapuskasing in Northern Ontario were low with 0.26 and 0.29% respectively. The samples from the Experimental Stations in Eastern and Central Quebec were of good quality in respect to calcium, Cap Rouge and Ste. Anne in Eastern Quebec analyzing an average of 0.39% and Lennoxville and Farnham in Central Quebec 0.38%.

Illustration Stations

Phosphorus in Oat Straw

The phosphorus content of the samples of oat straw have been low on the basis of average figures. Morrison shows the average figure for phosphorus in oat straw is 0.13%. This figure is reached and even exceeded in the best samples of each province but throughout the series many of the forages had a phosphorus content of less than 0.10% and a considerable number under 0.06%. The average figure is about 0.07% which is considerably lower than normal.

Undoubtedly this is a lower figure than that for the standing crop since other work has shown that the phosphorus compounds are lost in weathering much more readily than the calcium. The results of this investigation corroborate this statement. It cannot be stated, however, that in all cases where there is a low phosphorus content that the appearance of the herbage suggests that the small percentage of phosphorus can be attributed to weathering only. What other factors influence this ash constituent throughout the various districts it is impossible to say without further investigation, but in all localities the phosphorus content is low and in many samples seriously so.

Experimental Farms and Stations

On some of the Experimental Farms and Stations the phosphorus content of the straw was relatively high. At Charlottetown, Ste. Anne, and Farnham the samples were above average in this regard. At Cap Rouge the phosphorus was 0.11% or slightly below average, while at Kentville, Lennoxville, L'Assomption and Kapuskasing, as on the Illustration Stations, it was very low ranging only from 0.07 to 0.09%.

RESULTS OF CHEMICAL ANALYSES OF TIMOTHY HAY

The percentage of calcium and phosphorus in the samples of timothy hay from various districts in Eastern Canada are presented in Table 3.

TABLE 3.—PERCENTAGE OF CALCIUM AND PHOSPHORUS IN SAMPLES OF TIMOTHY HAY FROM VARIOUS DISTRICTS IN EASTERN CANADA

Locality	No. of samples	Calcium (water-free basis)			Phosphorus (water-free basis)		
		Maximum	Minimum	Average	Maximum	Minimum	Average
Prince Edward Island							
Illustration Stations	9	0.48	0.20	0.38	0.15	0.07	0.11
Experimental Station (Charlottetown)	1	0.37	0.39	0.39	0.13	0.13	0.13
Nova Scotia							
Illustration Stations	10	0.51	0.28	0.40	0.19	0.16	0.12
Experimental Station (Kentville)	1	0.56	0.56	0.56	0.09	0.09	0.09
New Brunswick							
Illustration Stations	17	0.45	0.18	0.31	0.15	0.09	0.12
Eastern Quebec							
Illustration Stations	8	0.52	0.24	0.39	0.13	0.10	0.11
Experimental Station (Ste. Anne)	1	0.31	0.31	0.31	0.14	0.14	0.14
Lake St. John							
Illustration Stations	1	0.29	0.29	0.29	0.09	0.09	0.09
Central Quebec							
Illustration Stations	9	0.53	0.26	0.41	0.18	0.01	0.11
Experimental Stations (Lennoxville and Farnham)	2	0.49	0.35	0.42	0.16	0.13	0.15
Eastern Ontario and Western Quebec							
Illustration Stations	8	0.44	0.30	0.39	0.16	0.11	0.13
Experimental Stations (L'Assomption)	1	0.40	0.40	0.40	0.12	0.12	0.12
Northern Ontario and Quebec							
Illustration Stations	15	0.48	0.23	0.41	0.17	0.08	0.12
Experimental Station (Kapuskasing) (Unfertilized)	2	0.53	0.45	0.49	0.12	0.11	0.12

* Including Northwestern Ontario.

DISCUSSION OF RESULTS OF CHEMICAL ANALYSES OF TIMOTHY HAY

Calcium

Illustration Stations

The average calcium content of timothy hay from Illustration Stations was fairly satisfactory. The figures for New Brunswick were lower than the other provinces and might be considered too low. Thirteen out of 17 samples were below 0.40% and the average for the province was 0.31%. Stage of maturity may account for this lower calcium content. Morrison shows considerable variation of this mineral at different stages of maturity; harvested after early bloom the average percentage of calcium is 0.41 while the crop harvested in full bloom averages only 0.27%. As timothy hay is usually harvested in this later stage the calcium content in general is well up to the average. There appears to be no evidence of calcium deficiency in the timothy hay samples from either Illustration Stations or Experimental Farms or Stations.

Phosphorus

Illustration Stations

The average percentage of phosphorus in the samples of timothy hay from Illustration Stations was 0.12. This is slightly lower than the 0.16% average of Morrison. A considerable number of samples had a normal phosphorus content and the average is not far below normal. There were, however, a large number of samples with less than half the average amount of this element. This low content may have been due to weathering and loss of leaf and it would seem advisable in future work to attempt to obtain samples which are free from the influence of these factors. Very little variations can be noted in the phosphorus content of the hay from various districts.

Experimental Farms and Stations

In general, the phosphoric acid content of the hays sent in by Experimental Farms is relatively high with the exception of Kentville. The low phosphorus and high calcium content of the Kentville samples suggest the probability of loss through leaching.

THE INFLUENCE OF LEGUMES ON THE MINERAL CONTENT OF HAY

As mentioned previously there were throughout the series scattered samples of timothy hay with an admixture of legumes sufficient to influence the composition. The calcium and phosphorus content of these samples have been determined and are presented in Table 4. For purposes of comparison the average analyses of pure timothy hay are also included in the table.

The figures in Table 4 show the value of legumes. Although the number of samples of pure timothy was not the same as those which included legumes the averages show definitely the higher mineral content where the legumes were present. The average calcium content was approximately 0.38% for pure samples, whereas the figures for hay with legumes ranged from 0.59 to 1.82%. The influence of legumes is not so marked on the phosphorus content but in each case the average is somewhat higher in this respect also.

TABLE 4.—COMPOSITION OF TIMOTHY HAY AS INFLUENCED BY AN ADMIXTURE OF LEGUMES

Locality	Calcium		Phosphorus	
	Timothy	Timothy and legumes	Timothy	Timothy and legumes
	p.c.	p.c.	p.c.	p.c.
Illustration Stations				
Prince Edward Island	0.38	0.90	0.11	0.21
New Brunswick	0.31	0.82	0.12	0.12
Eastern Quebec	0.39	0.83	0.11	0.14
Lake St. John	0.29	0.68	0.09	0.16
Central Quebec	0.41	0.71	0.11	0.14
Eastern Ontario and Western Quebec	0.39	0.59	0.13	0.13
Northern Ontario and Northern Quebec	0.41	0.87	0.12	0.12
Experimental Stations				
Cap Rouge, Quebec		0.63		0.19
Kapuskasing, Ont.	0.49	1.08	0.12	0.13

In this connection an interesting point arises regarding the samples from Kapuskasing, Ontario. Two samples were furnished from fertilized hay and two from unfertilized. The average percentage of calcium in the hay from the unfertilized plots was 0.46 as compared with 1.08 from the fertilized plots. The phosphorus averaged 0.12% in both the unfertilized and fertilized samples. It is possible that the fertilizing increased the calcium due to the indirect effect of encouraging the growth of legumes as the unfertilized plots contained approximately 87% timothy and 13% legume while on the fertilized area the legumes predominated with approximately 70% legumes and 30% timothy.

Due to so many variable factors little or no correlation could be found between the mineral content of the forages and the observed deficiencies in the live stock, the type of soil, and other points covered in the questionnaire. The low mineral content appeared to be equally as prevalent on heavy soils as on light soils, and low mineral content as determined by chemical analysis was not always associated with observed mineral deficiencies in the animals.

SUMMARY

1. These investigations include data on the mineral content of 119 samples of oat straw and 125 samples of timothy hay collected from Illustration Stations and Dominion Experimental Farms and Stations in Eastern Canada.

2. The chemical data are supplemented by information from questionnaires regarding feeding, evidence of mineral deficiency, soil type, etc.

3. Oat straw samples. The average calcium content of oat straw in the various districts was: Central Quebec 0.35%, Eastern Ontario and Western Quebec 0.36%, and Northern Quebec and Northern Ontario 0.34%, which is about normal for this mineral; in New Brunswick the content was 0.30% which is slightly below normal; in Prince Edward Island and Nova Scotia it was 0.28% and 0.26% respectively, which is considerably below average.

The average percentage of phosphorus was distinctly low throughout the series.

4. Timothy hay samples. The average calcium content of timothy hay was normal throughout. The lowest calcium was found in the New Brunswick samples but even here it was up to normal for timothy hay cut in full bloom.

The phosphorus content of the timothy hay is much nearer normal than in the case of straw. The average figure for the series was 0.12% while the standard as selected is 0.16%.

5. Legumes in the timothy hay increased the calcium content quite considerably and the phosphorus also to some extent.

ACKNOWLEDGMENTS

The authors wish to express their indebtedness to the staff of the Divisions of Illustration Stations, Animal Husbandry, and Botany for assistance in collecting and analyzing the samples of forage.

THE PLACE OF MINERALS IN SWINE NUTRITION[1]

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Your Secretary has asked me to discuss the place of minerals in swine feeding, and I must say at the outset that I have experienced a considerable amount of difficulty in finding literature which deals with this phase of swine nutrition in anything like a specific manner. Possibly this fact would warrant such a paper being included on the programme of this meeting, in order that the members of the organization will realize more forcefully the necessity for investigation relative to the mineral nutrition of swine.

In view of the fact that an extensive discussion is taking place to-day on the mineral nutrition of live stock I am assuming that ample consideration will be given to the minerals supplied by farm feeds, and that the evidences of mineral malnutrition will be outlined in a general way.

EVIDENCES OF MINERAL MALNUTRITION IN SWINE

Calcium and Phosphorus.—In any discussion of mineral malnutrition it is difficult to separate calcium and phosphorus, because bone metabolism and bone growth involve both elements to such a great extent, and because the adequacy of the intake of either element in covering the animal's requirements and in avoiding nutritive disaster depends so largely upon the intake of the other, particularly when the conditions for the assimilation of both are unfavourable in the absence of vitamin D or of ultraviolet radiation. About 99% or more of the body's store of calcium is found in the bones, while the proportion of body phosphorus so located, though quite variable depending upon the ratio of skeletal to soft tissues (and hence upon stage of growth) seems to be about 80%.

In the nutrition literature the pathological condition resulting from the nutritional disturbance of bone growth in very young animals is almost universally referred to as rickets. Biochemically this condition is characterized by subnormal levels of inorganic phosphorus or of calcium in the blood, and by low percentages of mineral matter in the bones. However, the pathological condition existing in the bone varies, being either osteroporosis or true rickets, the latter condition being clearly distinguished from the former, first, by the presence of the rachitic metaphysis, a marked widening of the epiphyseal cartilage, and, second, by its occurrence only in very young animals. A confusion of osteroporosis with rickets, merely because they have not been clearly distinguished biochemically is unfortunate from any standpoint and may account in part for the observed differences between species with reference to the relative vitamin D potency of different so-called "anti-rachitics".

Pregnant sows on low-calcium diets may become lame, have difficulty in farrowing, secrete little milk, and may raise only a small proportion of their young to weaning age.

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[1] An address delivered before the Eighth Annual General Meeting of the Canadian Society of Animal Production (Eastern Section) at the Central Experimental Farm, Ottawa, Ont., on June 16, 1937.

[2] Professor of Animal Husbandry.

However, swine may grow for many months with unimpaired vigour on cereal rations with no calcium supplements, provided vitamins A and D are made available in adequate amounts, and in young pigs it is unlikely that a phosphorus deficiency will occur under practical and normal conditions of feeding. On the other hand a calcium deficiency is to be expected unless special provision is made against it.

Theiler has said: "The normal functioning of the mineral metabolism of an animal depends upon the harmonious interaction of three dietary factors: vitamin, calcium and phosphorus. The absence of any one of them might be expected to have the same result in all animals, but in practice this does not seem to be the case. Some species react more readily to one deficiency than another."

An excess of either calcium or phosphorus in rations for swine will tend to impair the utilization of the other minerals and to induce deficiency symptoms.

Iodine.—Goitre is the result of a deficient supply of iodine in the food and water and is remedied by administering iodine to the breeding stock either as iodides or as iodized salt during the gestation period, or, in extreme cases, to all stock the year round.

Iron and Copper.—Among the many factors that probably contribute to the prevailing high death rate in suckling pigs is nutritional or milk anemia. This condition results from the exclusive feeding of milk to new-born pigs for periods of three to four weeks after birth, with no access to earth or vegetation, and is traceable to a deficiency in milk of iron and copper. Nutritional anemia is prevented in practical swine husbandry by assuring a supply of iron and copper to the new-born pigs. The nutrition of the sow prior to or during lactation is entirely unrelated to the occurrence of nutritional anemia in her pigs.

Sodium and Chlorine.—The breakdown in health due to lack of salt is marked by "loss of appetite", a generally haggard appearance, lustreless eyes, a rough coat, and a very rapid decline in live weight.

There is apparently a close relationship between sodium requirements and the adrenal glands, such that large doses of sodium chloride relieve the symptoms of adrenal insufficiency.

AVAILABILITY AND UTILIZATION OF MINERALS

The utilization of minerals in the ration is modified by many factors relating to the ration or to the environment. The chemical combination in which a mineral occurs in the ration, concentrations of other minerals and inorganic radicals, the concentrations of certain of the organic nutrients, particularly the vitamins, the accessibility of sunlight to the animal, may all depress or increase the utilization of the mineral in digestion and in metabolism.

Vitamin D.—The proper assimilation of calcium and phosphorus in the young growing animal is dependent upon an adequate supply of vitamin D, either by adequate exposure of the animal to sunlight, or to some other source of ultraviolet light, or by the incorporation in the ration of food materials rich in vitamin D. The indispensability of vitamin D in the nutrition of the adult pig has not been satisfactorily established.

MINERAL REQUIREMENTS OF SWINE

The total requirements of growing swine for calcium and phosphorus (with adequate vitamin D provided), expressed as a percentage of the ration fed, have been assessed as follows:

Calcium requirement— 0.34% or less—Dunlop
0.37%—Axelsson
0.30%—Spildo

Phosphorus requirement—between 0.27 and 0.30%—Hughes & Aubel
between 0.30 and 0.35%—Garrigus & Hunt
0.53% or less—Dunlop
0.20%—Axelsson
0.38%—Spildo

Thus, taking an average of these recommendations, the requirements are not far removed from 0.30% for both calcium and phosphorus.

The utilization of feed calcium is assumed to be 70%, largely on the basis of results of the Illinois Station on the calcium and phosphorus metabolism of growing swine.

> Spildo estimates the growth requirements of pigs to be 5.0 grams of dietary calcium and 5.7 grams of dietary phosphorus, based on a day's gain in body weight of 500 grams, containing 0.58% of calcium and 0.57% of phosphorus. The percentage assimilations are taken at 60 for calcium and 50 for phosphorus. The growth requirements, expressed in ration percentages, would be 0.25% of calcium and 0.28% of phosphorus. The percentages given above include a maintenance quota assessed according to the Sherman method.

The necessary percentages of calcium and of phosphorus decrease as the size of the pig increases.

Hogan has estimated that the rations of brood sows should contain not less than 0.4% of calcium for the most successful reproduction, as judged by the offspring produced and a study of the bones of the sow.

The necessary calcium level increases during pregnancy from 0.22% up to 0.43% on the dry ration, and the necessary phosphorus level from 0.19% to 0.28%. The daily depositions of calcium and phosphorus for fetal growth are about equal at the eighth week of gestation, while at the sixteenth week, more than twice as much calcium as phosphorus is deposited daily. At parturition, the products of conception for an average litter of eight pigs contain 101 grams of calcium and 60 grams of phosphorus.

No quantitative information has been found of the calcium and phosphorus requirements of lactating sows as determined by feeding tests of any description. The extra requirements will of course depend upon the amount of milk produced and its composition. On the basis of the interesting study of Hughes and Hart, it may be computed that sows produce an average of 6.8 pounds of milk daily during a lactation period of 8 to 12 weeks, the maximum production being attained between the second and the fourth weeks. The composition of the milk varies considerably throughout the lactation period; on the average it contains 0.277% of calcium, 0.165% of phosphorus, and 1.44 calories of gross energy per gram. An average day's production (3084 grams) contains

8.54 grams of calcium, 5.09 grams of phosphorus, and 3434 calories of gross energy.

The Requirements for Iron and Copper.—No quantitative information in regard to the requirements of farm animals for iron and copper is available.

Undoubtedly the need of iron and copper for hemoglobin production and regeneration determines to a large extent the total requirement for these metals. However, the fact that it is possible to increase the iron and hemoglobin content of the blood of pigs above what may be considered normal or adequate levels does not indicate that ordinary rations should receive iron supplements until some definite benefit to the animal is shown to follow this hyperhemoglobinemia.

The iron or copper requirements of the animal may be greatly increased if it is producing products rich in these metals. For example, a pregnant sow stores up a total of 580 mgms. of iron in the products of conception and in the last three weeks of pregnancy she is storing iron at the rate of 9 to 12 mgms. daily, probably equal to several times her own body requirements.

The requirements for Iodine.—Orr and Leitch, in a very thorough review of iodine in nutrition, state: "Regarding the iodine requirements of farm animals we have no definite information. Nor can we deduce the requirement of animals from a knowledge of the amount required to prevent goitre, for as yet no standard and adequate dosage has been determined." However, from the iodine content of feeds and usual consumptions they have computed about the amounts of iodine that different kinds of animals consume daily in non-goitrous areas. Their estimates for swine follow:

	Body wt., lbs.	Daily iodine consumption (micrograms)
Pigs, weaned	50	40–80
Sows	400	200

Welch recommends three grains of potassium iodide weekly for pregnant sows for three months, and a total of 1.2 grams, equivalent to 10.2 mgms. daily, although admitting that this is probably at least three times as much as needed.

Salt (NaCl) requirements. Morrison and Evvard recommend for swine 0.03 to 0.12 ounce of salt per head daily.

Water requirements of Swine Water requirements are ordinarily not considered along with mineral requirements, but no apology is needed for considering water in a paper of this sort, since water is a mineral and since the intake of minerals is one of the determinants of the requirements of water.

The amount of water needed by an animal is increased by the loss of water (a) in the pulmonary circulation, determined by the rate of ventilation, the percentage saturation of the inspired air, and the temperature of the body, (b) insensible perspiration through the skin, bearing a definite relation to the heat loss from the body for a definite environmental temperature and for definite humidities above a certain high percentage

saturation, (c) the sensible perspiration, related to the amount of muscular exercise and to atmospheric conditions, and (d) the alimentary output of water, related to the amount and character of the food consumed.

PRACTICAL CONSIDERATIONS

Nutritional Anemia may be prevented by the direct feeding of reduced iron or a commercial iron salt such as ferric sulphate or ferric chloride. A practical method is to place in the pen sods or earth to which an iron salt has been added.

Phosphorus.—Since the cereal grains themselves (with the exception of rice) contain 0.3 to 0.4 or somewhat more of phosphorus and since the usual protein supplements are much richer than this in phosphorus, it seems clear that rations for growing swine do not require supplemental quantities of this mineral.

Calcium.—The calcium deficiencies of a ration may be adequately taken care of by the supplemental feeding of ground limestone or calcium carbonate. In the instance of skimmilk or protein-rich concentrates of animal origin being fed there is not such a probability of a calcium deficiency as when protein concentrates of vegetable origin are fed.

As a source of both calcium and phosphorus feeding bone meal may be fed.

The feeding of the pregnant sow with respect to calcium and phosphorus is quite similar to that of the growing pig; as she progresses in pregnancy her mineral needs approximate in intensity more and more nearly those of the weanling pig, so that during the last week of pregnancy she requires about as large a concentration of calcium and of phosphorus in her ration as does a 50-pound pig. A lactating sow, requiring an average of 0.45% of calcium and 0.37% of phosphorus in her ration on the dry basis, also presents the same sort of a picture as the weanling pig.

Vitamins.—The provision of a dependable source of the vitamins is necessary to mineral assimilation. Sufficient literature relative to this phase of nutrition is available and it remains for the feeder to make use of opportunity.

Goitre with its accompanying complications may be prevented by the feeding of iodine along with the regular ration.

ACKNOWLEDGMENT

The greater part of this data has been collected from Bulletin No. 99 of the National Research Council, *Mineral Nutrition of Farm Animals* by H. H. Mitchell and F. J. McClure.

THE PROBABLE EFFECT OF NUTRITION ON THE BUTTERFAT TEST WITH PARTICULAR REFERENCE TO MINERALS[1]

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Much yet remains to be worked out in the explanation of the phenomenon of milk secretion. Early workers definitely state that the butterfat test of milk, while it varied within certain limits, was a hereditary factor and not appreciably influenced by feeding. Present day evidence would indicate that this early hypothesis is only partially true. It still appears to be a fact that the normal butterfat test of a cow is largely fixed by heredity and cannot be increased beyond certain more or less fixed limits. On the other hand, it has been demonstrated that improper feeding, and more particularly prolonged underfeeding of some or all nutrients, will result in a reduction in both the yield of milk and the butterfat test. When this condition is corrected the test rises to the inherited ability of the cow, but not beyond this point. It should also be appreciated that there is a difference in the behaviour of the cow and the composition of the resultant production between a starvation diet and partial deficiency ration.

Since the program at this meeting is built largely around the subject of minerals and their deficiencies, it is desirable at this point to list the most important mineral elements that might be deficient in the ration. Sodium and chlorine make up salt, and all live stock men know that salt is necessary in the ration, and that unsatisfactory results occur if it is not fed. In many parts of the Dominion the soils are low in iodine with a resultant shortage of this mineral in the crops grown on these soils. Calcium may be deficient in some sections but shortages do not occur where cows are fed large quantities of legume hay. Phosphorus shortages are found in many sections of the Dominion and in many live stock countries throughout the world. Shortages in minerals are, in cattle feeding, largely confined to sodium and chlorine (salt), iodine, calcium and phosphorus. Many other minerals are required in the ration of the dairy cow but with few exceptions definite shortages have not yet been reported or, at least, not diagnosed.

Shortages of iodine have been largely demonstrated in the new born young (goitre). Latterly, however, there has been evidence indicating that this element may have a very marked influence on both milk yield and fat test. Graham (1) found that after removing the thyroid gland a marked drop occurred in both yield and test, and by adding thyroxin, a hormone secreted by the thyroid gland, the yield of milk and fat increased significantly. While the feeding of this hormone is not yet feasible in dairy feeding practice this work does demonstrate two things at least, first, that milk and fat secretion is a very complex phenomenon and not

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[1] An address delivered before the Eighth Annual General Meeting of the Canadian Society of Animal Production (Eastern Section) at the Central Experimental Farm, Ottawa, Ont., on June 16, 1937.

[2] Associate Professor of Animal Husbandry.

controlled by any single factor and, second, from a practical standpoint, marked iodine deficiencies may be one limiting factor in some dairy herds. Just here it might be well to warn against excesses in the feeding of iodine since this may result in a serious breakdown in health. (One ounce of potassium iodide in 300 pounds of common salt is the mixture recommended by many authorities.)

In some sections of the Dominion calcium deficiencies are in evidence, but where legume hays, such as alfalfa, red clover or alsike are fed as the hay portion of the ration, calcium deficiency is not likely to occur. With classes of live stock such as hogs that do not eat large quantities of roughages, calcium deficiencies are more common than with other classes of stock. Since calcium deficiencies are apparently rare in cattle feeding, and since there is little information in the literature on the effect of calcium on butterfat test, the discussion on this particular mineral will be discontinued at this point.

Phosphorus deficiencies have been reported in many parts of the world and are frequently found in cattle fed largely on home-grown rations. This condition has been reported as fairly prevalent throughout Old Ontario and is more particularly pronounced in the western sections of Old Ontario. Most animal husbandrymen are familiar with the emaciated condition of cattle that are fed insufficient quantities of phosphorus. Considerable work is under way at the present time to determine if this deficiency has an effect on the butterfat test of milk, and indications at the present time point to some rather interesting results. The addition of steamed bone meal or di-sodium phosphate to home grown rations fed to dairy cows in certain cheese factory sections where the butterfat test for entire herds was running below 3% has resulted in an increase in the butterfat test in most instances. Whether this is due directly to the increase in phosphorus in the diet, or to the better assimilation of all of the nutrients when phosphorus was added to the diet, or to improved appetite, is a problem that has not yet been solved. This point must be kept in mind, however, that the herds that were testing lower than 3% were apparently not testing up to the normal inherited ability of the cows for butterfat. It is not suggested, and there is no evidence to support the statement, that phosphorus will increase the butterfat test of a cow's milk beyond her inherited ability to produce, but on the other hand, it will apparently help in bringing cows back to their normal level.

Rations that are balanced with protein rich feeds that have as a general rule a high phosphorus content, feeds such as bran, shorts, cottonseed meal and oilcake meal, will usually supply sufficient quantities of phosphorus to keep a cow up to her normal level of fat test. Where low phosphorus hay is fed and the ration made up largely of home grown grains that have been grown on soils that have a low phosphorus content the addition of some phosphorus rich mineral feed is advised. Steamed bone meal is recommended for this purpose, and evidence would indicate that in phosphorus deficiency areas it should be fed at the rate of about two pounds of steamed bone meal to each 100 pounds of concentrates supplied. Where the cattle are not fed concentrate feeds this product may be fed *ad lib* in a box in the pasture field or mixed with the salt at the rate of approximately 50% bone meal and 50% salt.

The following table will serve to illustrate the importance of feeds as sources of calcium and phosphorus:

(2) *Feeding Stuff* (2)

	Calcium %	Phosphorus %
Concentrates:		
Barley grain	0.05	0.38
Oats	0.09	0.33
Wheat	0.03	0.43
Corn	0.01	0.28
Oilcake	0.33	0.86
Cottonseed (41% protein)	0.20	1.19
Wheat bran	0.12	1.32
Distillers' corn grains dried	0.05	0.31
Bone meal steamed	32.61	15.17
Roughages:		
Alfalfa hay	1.43	0.21
Timothy hay	0.27	0.16
Oat straw	0.36	0.13
Corn silage	0.07	0.06

There is evidence to indicate that the increased use of inorganic minerals in the form of di-calcium phosphate or di-sodium phosphate may occur in the near future. New methods in the preparation of phosphates insure a product free from injurious quantities of flourine. These products have also the advantage of being more readily available than bone products, and if the price per unit of phosphorus becomes more attractive in these feeds than in bone meal an increase in their use would be expected.

Excess quantities of calcium in a ration tend to precipitate the available phosphorus and may actually aggravate phosphorus deficiencies. The writer has seen some of the most typical cases of phosphorus deficiency on farms where large quantities of alfalfa hay were fed along with a concentrate mixture made up entirely of home grown grains. From the standpoint of supplying nutrients this type of ration is quite satisfactory but it is very high in calcium and low in phosphorus. The addition of any mineral feed that contains a large amount of calcium to a ration similar to the one mentioned above is not recommended. Phosphorus rich feeds and phosphorus rich minerals should be used.

One of the unfortunate features of many of the home-mixed and commercial-mixed mineral feeds is that they contain a large amount of calcium and when fed under conditions where the ration already has an excess of calcium may actually do more harm than good. Most of the experimental work done with minerals would indicate that the simple recommendation of the liberal feeding of well balanced rations supplemented with iodized salt and steamed bone meal will supply the protein, energy, vitamins and minerals required for a cow during the lactation period and dry or fitting period.

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REGULATION OF MINERAL FEEDS UNDER THE FEEDING STUFFS ACT[1]

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The present Feeding Stuffs Act has been in effect since 1920 without change in the guarantee requirements applicable to commercial feeds. It provides no authority to require chemical guarantees other than protein fat and fibre, and consequently could not be applied to regulate the sale of mineral mixtures and various other products which have become of commercial importance during recent years.

During the past session of Parliament a new law, termed The Feeding Stuffs Act, 1937, was passed to come into effect on October 1 of this year. Many technical authorities, including a good number of those present here, and also many representatives of consumer and trade interests were consulted and contributed most helpfully in the development of its provisions. It embraces a wide range of products, the term "feeding stuff" being defined as "any article intended for consumption by live stock and purporting to supply proteins, carbohydrates, fats, minerals, condiments or vitamins, and shall include any article prepared for the purpose of preventing or correcting nutritional disorders."

During recent years a great deal has been heard regarding the mineral nutrition of live stock. For the most part scientists have been recommending relatively simple mineral mixtures. Progressive manufacturers endeavour to keep their products in line with scientific developments and teachings, but there are always elements in the trade which seek to capitalize on any subject of popular interest. Complex proprietary mineral mixtures, offered at high prices, and supported by extensive advertising, extravagant claims and high-pressure salesmanship, have become a matter of serious concern to all interested in the welfare of the live stock industry. With no guarantees required and no uniformity in analyses claimed by different manufacturers, neither feeders nor technical authorities were in a position to appraise the value or suitability, either relative or absolute, of such products; hence the need and pressing demand for some legislative control as a protection to feeders and legitimate commercial enterprise.

Under the new feed law, straight mineral mixtures, as well as supplemental feeds purported to supply both proteins and minerals in excess of the amounts required in complete or balanced meal mixtures, are subject to registration, and packages must be labelled to show:—

(a) The name and address of the registered owner;
(b) The brand and name;
(c) The registration number;
(d) The net weight of contents;
(e) The specific name of each ingredient;
(f) The guaranteed analysis setting forth the actual amounts (within permitted tolerances) of such of the following as are intentionally or purportedly present: Calcium (Ca), Phosphorus (P), Iodine (I), Iron (Fe) and Salt (NaCl).

[1] An address delivered before the Eighth Annual General Meeting of the Canadian Society of Animal Production (Eastern Section) at the Central Experimental Farm, Ottawa, Ont., on June 16, 1937.
[2] Chief, Feed Division.

While other mineral elements are required by animals, they are usually present in adequate amounts in ordinary feed; hence, in the opinion of authorities consulted, there was not need to require guarantees of chemical constituents additional to those cited.

It will be noted that only those mineral constituents which are intentionally or purportedly present need be guaranteed; in other words, where one of the listed minerals is present only incidentally as a constituent of some other ingredient, it need not be declared unless special claims for it are being made. Attention is also directed to the fact that the various minerals must be guaranteed in actual rather than minimum or maximum amounts, and, with the exception of salt, as elements rather than compounds. The primary purpose in this is to facilitate calculation of calcium phosphorus ratios, such ratios being regarded as important. Mineral constituents of feeding stuffs, as reported in the most recent edition of "Feeds and Feeding" by Morrison, are given on this basis.

Obviously, where guarantees must be given in actual amounts, some tolerances must be recognized to take care of normal variations in the composition of ingredients and also the difficulties in mixing to secure absolute uniformity. The Act provides authority to establish such tolerances by regulation. Unfortunately we have not the benefit of experience to guide us in this matter, but, after consultation with a number of feeding authorities and chemists, tentatively suggest the following:—

(a) A deficiency or excess of one-tenth of the respective amounts of calcium (Ca), phosphorus (P) and salt (NaCl) guaranteed with a maximum deficiency or excess of 3% of the bulk;

(b) A deficienty of one-tenth of the respective amounts of iodine (I) and iron (Fe) guaranteed.

With mixed supplements as well as straight mineral mixtures subject to guarantees, different commercial preparations will vary widely in the contained amounts of any specific mineral. Accordingly it was considered that the tolerances should be a percentage of the guarantee rather than a specific amount. Neither the matter of ratios nor the probable additions in excessive quantities being involved with iodine and iron it seems unnecessary for these to fix tolerances above as well as below guarantees.

Apart from bone meal, single materials sold for mineral nutrition are not subject to registration under the Act, but authority is given the Governor-in-Council by regulation to require labelling with appropriate particulars of the character and quality of products not subject to registration but included under the definition for "feeding stuff" previously quoted. Bone meal must be labelled with a guarantee of calcium and phosphorus, also the minimum protein and, if in excess of 5%, the maximum fat.

In addition to the labelling and guarantees outlined, there are other features of the new Act which have a bearing on mineral feeds. Its provisions apply to advertising as well as to sales, and penalties are provided where any feeding stuff, either in relation to the product or to the provisions of the Act, is labelled or represented incorrectly or in a manner likely to deceive any person. Furthermore, authority is provided to detain or seize any feeding stuff offered in violation of the provisions of the Act, and

withhold it from sale until it has been made to comply with requirements. These provisions should be very helpful in securing effective application of the law, as similar provisions in other laws have proven themselves to be.

The degree to which this legislation will serve its needed and intended purpose will depend as much upon those who are conducting experiments and researches in animal nutrition as upon those immediately responsible for its administration. An enlightened purchasing public is the most effective weapon against unethical and uneconomical trade practices, and at the present time feeders are greatly in need of enlightenment on matters of mineral nutrition. A knowledge of what is right and what is wrong, based on facts and not opinions which may differ, is necessary as a basis for legal action, for the most vigorous defence in cases of prosecution is usually made by the most deliberate and flagrant offender, who relies on his astuteness to escape conviction and penalty and to maintain himself in a shady but lucrative business. Whatever this society may be able to accomplish, therefore, in the way of providing to feeders and law enforcement officers uniform and widely supported data on animal nutrition, and particularly with regard to mineral nutrition, will be most welcome and helpful.

EIGHTH ANNUAL MEETING OF THE CANADIAN SOCIETY OF ANIMAL PRODUCTION (EASTERN SECTION)

The eighth Annual General Meeting of the Canadian Society of Animal Production (Eastern Section) was held at the Central Experimental Farm on June 16, 1937. The preparations and plans for the meeting were made by members of the executive and it was decided that in view of the importance and widespread interest of the mineral question in the live stock industry of Canada, this subject warranted the consideration of the Society.

The meeting, carried out under the chairmanship of the President, Professor A. R. Ness, Macdonald College, Quebec, was well attended and proved to be very successful. The papers presented at this session were assembled for publication in *Scientific Agriculture* by the incoming Secretary, Dr. McKenzie.

At the conclusion of the meeting the following officers were elected for the ensuing year:—

President: Professor A. R. Ness, Macdonald College, P.Q.

Vice-President: Professor R. G. Knox, Ontario Agricultural College, Guelph, Ont.

Ontario Director: Mr. L. E. O'Neill, Department of Agriculture, Toronto, Ont.

Quebec Director: Mr. S. J. Chagnon, Department of Agriculture, Quebec, P.Q.

Maritime Director: Mr. W. W. Baird, Experimental Farm, Nappan N.S.

Secretary-Treasurer: Dr. C. D. MacKenzie, Experimental Farm, Ottawa, Ont.

SWINE DISEASES IN WESTERN CANADA[1]

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A request for a representative of the Department of Agriculture to address the Canadian Society of Animal Production on, "Swine Diseases in Western Canada", passed to me, left me somewhat perturbed. It would be much easier to speak on one particular disease as we find it and know it, than on swine diseases in general as said to occur in Western Canada, and the very complex problems with which they are involved. There immediately come to mind questions such as: Do swine diseases in Western Canada differ much from those in Eastern Canada? If so, what diseases are peculiar to the West or to this or to that Province or locality? Are diseases of swine significantly more prevalent and of greater economic importance in the West? Is the disease picture dominated by any one particular or specific infectious disease, or a nutritional or mineral deficiency disease, or a problem relating to parasitical infestation; or, are swine more prone to disease in general under Western conditions of swine raising than in the East?

What follows is no more than an attempt to picture the disease situation and to have it discussed so as to indicate practical means of improving it and the terms on which swine husbandmen, *i.e.*, the farm and fieldmen, and scientific workers can best get together in a co-operative effort to solve the problems involved.

For several years past there have been rumours and reports of heavy losses in swine from diseases in Western Canada. Few of these reports have come to us direct from owners or breeders who had themselves experienced the losses reported. In several instances, where close inquiry was made, it was ascertained that no unusual losses had occurred.

During the past few months we have been in correspondence with persons who might be in a position to furnish information and state or define the chief problems in swine diseases that could be reviewed and intelligently discussed at this meeting.

Grateful acknowledgment is here made of the interest and assistance given by the Chief Veterinary Inspectors for the Provinces of Manitoba, Saskatchewan, Alberta, and British Columbia, and by veterinary officers and practitioners in the said Provinces.

Swine Diseases as Recognized at the Abattoirs

It may be profitable to first obtain a general view of the picture of swine diseases in Canada as a whole, and in this it may be helpful to first examine the figures covering hog carcass condemnations at the various packing house establishments, as furnished by the Meat Inspection Services of the Health of Animals Branch. It will suffice for this purpose to summarize the figures for the past three years.

[1] Presented at a meeting of the Canadian Society of Animal Production—Western Section, at the University of Saskatchewan, Saskatoon, June 29, 1937.

[2] Chief Pathologist, Health of Animals Branch, Dominion Department of Agriculture, Ottawa, Canada.

TABLE 1.—HOG CARCASS CONDEMNATIONS—1935–36–37

Condemnations	1934–35		1935–36		1936–37		Total	
	No.	%	No.	%	No.	%	No.	%
Tuberculosis	4,808	48.5	3,632	41.2	4,243	40.4	12,683	43.4
Arthritis	1,019	11.2	1,279	14.5	1,586	15.1	3,884	13.3
Pyaemia and Septicaemia	922	9.3	946	9.5	939	8.9	2,707	9.2
Pneumonia	801	8.0	785	8.9	759	6.3	2,345	8.0
Pleurisy	349	3.5	308	3.5	331	3.1	988	3.4
Emaciation	327	3.3	219	2.5	418	3.9	964	3.3
Peritonitis	228	2.3	301	3.4	441	4.2	970	3.3
All other causes	1,457	14.7	1,451	16.4	1,786	17.0	4,694	16.1
Total	9,911		8,821		10,503		29,235	
Total kill	2,862,125		3,812,898		3,821,602		9,496,625	
Per cent condemned		0.34		0.31		0.27		0.30

The year 1934–35 shows a total kill of 2,862,125 hogs, and carcass condemnations amounting to 9,911, or 342 per 100,000 (0.34%); for 1935–36, a total kill of 2,812,898; carcass condemnations, 8,821, or 310 per 100,000 (0.31%); and for 1936–37, a total kill of 3,821,602; carcass condemnations 10,503 or 272 per 100,000 (0.27%).

Tuberculosis accounted for nearly one-half of the total carcass condemnations. It should be noted here that the figures given refer to carcasses only and not to portions of carcasses. Carcass condemnations for tuberculosis are given as 48.5% for the year 1934–35; 41.2% for 1935–36, and 40.4% for 1936–37, showing a reduction of 8% in the three years.

The next disease in order of importance in respect to carcass condemnations is arthritis, which accounted for 11.2% in 1934–35; 14.5% in 1935–36; 15.1% in 1936–37, showing an increase of 4% in three years.

Pyaemia and septicaemia come next with an average of 9.2%; followed by pneumonia, 8%; pleurisy and peritonitis, 6.7%; and all other causes, combined, 16.1%. These figures obtain for the whole of Canada. What differences, if any, are to be found in the figures pertaining to diseases and condemnations of hogs arriving at Eastern and Western establishments, respectively? Table 2 gives the comparison for the year 1936–37.

TABLE 2.—HOG CARCASS CONDEMNATIONS—1936–37

Disease	Establishments				Total	
	Eastern		Western			
	No.	%	No.	%	No.	%
Tuberculosis	2,744	49.0	1,499	30.5	4,243	40.4
Arthritis	911	16.3	675	13.7	1,586	15.1
Pyaemia and Septicaemia	277	5.0	662	13.4	939	8.9
Pneumonia	237	4.2	512	10.4	759	7.3
Pleurisy and Peritonitis	392	7.0	380	7.7	1,381	7.3
Emaciation	227	3.9	172	3.5	418	3.9
All other causes	813	14.5	1,009	20.0	1,786	17.0
Total	5,594		4,909		10,503	
Total kill	2,017,434		1,804,168		3,821,602	
Per cent condemned		0.27		0.27		0.27

It is seen that the carcass condemnation percentage of the total kill is identical for the Eastern and Western establishments, namely 0.27%. In respect to the classified diseases, the condemnations for tuberculosis are considerably higher, as might be expected, in the East, 49%, than in the West, 30%. Arthritis accounts for 16.3% in the East and 13.7% in the West; these two diseases accounting for 65.3% in the East and 44.2% in the West, of all carcass condemnations. On the other hand, pyaemia, septicaemia, and pneumonia account for more condemnations in the West, 23.8%, than in the East, 9.2%. It is true that many Western hogs arrive at Eastern abatoirs, but the reverse does not take place, so that the Western figures apply only to Western hogs, and indicate the diseases found in those hogs as they reach the market.

Diseases of Swine as Occurring on the Farm and Premises Used for Hog-raising

To what extent do the diseases recognized at the abattoir represent the disease picture on the farm? Tuberculosis and arthritis are chronic, insidious diseases, slow in development. As a general rule these diseases commence early in the life of swine and are the cause, as previously mentioned, of 50% or more abattoir condemnations of whole carcasses (and for the major bulk of portions of condemned carcasses). It is evident, therefore, that these two diseases are of major importance in swine raising, and the cause of a heavy portion of the losses. In addition to these, the following may be named; hog cholera or swine fever, pneumonia, necrotic enteritis, haemorrhagic septicaemia, erysipelas, skin diseases (urticaria erythema), pyaemia, and abscesses; an important group of nutritional and deficiency diseases which include anaemia, goitre, rickets, paralysis, etc.; mange, and parasitic diseases caused by worm infestation.

No reliable data are available by which it would be possible to name the diseases of swine in Western Canada in the order of their incidence, sequence, and economic importance, or to indicate in figures the losses and mortality caused by each of them. The following brief statements have been derived and condensed from information obtained from Government officers, veterinarians, and other sources.

Manitoba

Haemorrhagic septicaemia, diseases of malnutrition, anaemia and calcium deficiency, round worm infestation, and sarcoptic mange are said to be the diseases of principal importance, and the cause of the heaviest losses.

Saskatchewan

Haemorrhagic septicaemia, swine erysipelas, infectious enteritis, coccidiosis, mange, and diseases of the new-born (goitre, anaemia), of which the two first named, haemorrhagic septicaemia and erysipelas, are seemingly of major importance.

Alberta

There have been more reported losses in swine from disease in Alberta, and more alarm expressed in this connection, than in any other Western Province. This may be due, in part at least, to the fact that more hogs

are raised in Alberta than in the other Provinces. The diseases of swine in Alberta reported or suspected do not differ in kind from those of Saskatchewan and Manitoba. Reports of heavy losses, especially in very young pigs on the premises where a large number of hogs are raised have been investigated, and while some have proved more or less correct, most of them have been found greatly exaggerated. If the mortality rate is somewhat higher in Alberta, no evidence has come to us of it being significantly higher.

British Columbia

In hogs raised and bred in the Province, it is said that few troubles are encountered, and that those are mainly attributed to faulty feeding, particularly of sows and young pigs. Large numbers of feeder hogs are imported, principally from Alberta, and go to the premises of garbage feeders. In many consignments the animals are said to be in a very unthrifty condition at the time of purchase and it is among these, following long train journeys and sudden changes from grain to a garbage diet, that heavy losses sometimes occur; which, under such circumstances, is not at all surprising.

Hog Cholera

It may be stated, first of all, that from all inquiries made and the information returned, there is no suggestion of a specific infectious and contagious disease, spreading from farm to farm or from district to district. Years ago, there were occasional extensive outbreaks of hog cholera or swine fever. This highly infectious, reportable disease is known all over the world. In many countries it is widespread and firmly rooted, and is the greatest problem in swine disease and prevention. In Canada, as a direct result of the Government policy and stringent regulations pursued for the past thirty or more years, it is never able to establish itself and is promptly eliminated by drastic means and the refusal to permit the use of cholera virus for vaccination purposes which serves to perpetuate sources of infection. The control and elimination of hog cholera has saved the swine industy in this country many millions of dollars, an achievement that is rarely or insufficiently appreciated.

Tuberculosis

A disease of a more insidious nature, and therefore more difficult to detect and control, is tuberculosis. The progress made in eradicating this disease in cattle, by drastic means, has been and is highly satisfactory. Similar means have not yet come into practice for the control and eradication of swine tuberculosis which, in some quarters at least, appears to be becoming more prevalent. The primary cause of tuberculosis, as is well known, is the tubercle bacillus, of which there are three recognized types human, bovine, and avian. Swine are highly susceptible to the bovine and avian types, and to the latter is attributed the increasing incidence of swine tuberculosis; the source of infection being tuberculous poultry flocks, with which swine are so frequently in contact.

Swine Erysipelas and Arthritis

Swine erysipelas has for generations been known and dealt with in European countries as a swine disease problem of major importance. Until recent years this disease was regarded as an almost negligible factor

in swine raising in North America, where it appeared to occur only in its more benign form of urticaria, known as "Diamond Skin Disease". But lately it has attracted much more attention in the United States where it is becoming increasingly prevalent and appearing in its more acute and serious forms. Also in Canada, swine erysipelas is gaining ground and receiving more recognition. The disease may occur in either an acute or a chronic form, in which there is a wide range of clinical manifestations. A septicaemia is characteristic of the acute type of the disease which may end fatally within 24 to 48 hours of the onset of symptoms. The chronic type of the disease frequently involves the joints and the valves of the heart. It would be hazardous to express an opinion with regard to the incidence of the acute, septicaemic form of erysipelas in Canadian swine which is possibly confused with septicaemic conditions arising from other causes. Arthritis, mentioned before, accounts for a relatively high percentage of swine condemnations at the abattoirs, and it is quite possible that the greater number of these are co-related to or are actual manifestations of swine erysipelas. Fulton (Can. Jour. Res. 1933) has studied swine erysipelas as he observes it in the Province of Saskatchewan and has isolated from affected joints strains of the specific mirco-organism which causes this disease. A research study of arthritis in swine arriving at the abattoirs is being carried on by the Pathological Division, Health of Animals Branch. The vagaries in the development and course of swine erysipelas, the fact that the organism may exist for long periods of time almost as a harmless parasite and then assume an exalted virulence, and the varying susceptibility of swine to the disease make it a difficult one for diagnosis and control.

Infection is frequently associated with arthritis and rheumatoid conditions. But there are, undoubtedly, various conditions and health disturbances which predispose to or even originate the disease. Improperly balanced food rations with a lack of essential vitamins and minerals, improper housing with inadequate shelter and protection, constitutional weakness and an inherited predisposition are factors which singly or in various combinations may lead to rheumatic infection and arthritic disease. It has to be recognized that arthritis, although a frequent manifestation in the chronic type of erysipelas, may occur independently of that disease.

Haemorrhagic Septicaemia

A large group of diseases characterized by haemorrhages in the various organs and animal tissues, occurring in practically all species of farm animals and poultry, also in buffalo and some kinds of wild animals, and related to the presence in the circulating blood and tissues of a well recognized micro-organism, fall under the designation, "hemorrhagic septicaemia". The genus to which these micro-organisms belong has been named *Pasteurella*, hence pasteurellosis is another term for these infections and, in swine, is synonymous with haemorrhagic septicaemia and swine plague with which, for the most part, sporadic or enzootic swine pneumonia is included. The disease rarely, if ever, occurs as a true epizootic and, as a rule, only a few animals are affected at any one time in any given place or premises or in the same swine herd. It does occur, for the most part, as a complication of some other disease, such as, for example, hog cholera or swine fever; not as a primary cause but as a secondary and contributory

infection. The fact that it is so frequently encountered in association with some other highly contagious disease and so rarely occurs as an independent disease is often overlooked; also, the fact that pasteurella organisms may be found normally inhabiting swine and the soil and water to which swine have access. However, the virulence and invasive powers of pasteurella are changeable and may be exalted or lowered according to the susceptibility or resistance of the animals through which it passes. Nevertheless, it is important to keep in mind the fact that this infection in swine is much more likely to be a secondary and not a primary disease factor. For in spite of this it appears that haemorrhagic septicaemia is uppermost in the minds of many swine husbandmen and veterinarians; and that in the Western Provinces, and probably in the East as well, a diagnosis of haemorrhagic septicaemia is made on the farm more frequently than the diagnoses of any or all other swine diseases. It has become a habit apparently to designate swine pneumonia, acute or chronic, or in whatever type or form it is observed, as haemorrhagic septicaemia, and not only the pneumonias, but many other conditions associated with cough and respiratory troubles, enteritis, weakness, unthriftiness, etc. Some veterinarians go so far as to say that haemorrhagic septicaemia is the disease of principal importance occurring in their districts or provinces, and accounts for the bulk of the losses and mortality in swine. Very little evidence for such assertions and assumptions has been presented and it may well be questioned if the diagnoses of haemorrhagic septicaemia as usually made and the views commonly held in respect to the significance of this disease are in any way indicative of its actual occurrence and prevalence and of its true place in the picture of swine diseases.

Haemorrhagic septicaemia is said to occur in peracute, acute, subacute and chronic forms, thus covering a wide range of pathological manifestations: febrile, inflammatory, haemorrhagic, enteric and pneumonic. But fever and depression, petechiae and small haemorrhages, acute, chronic and necrotic pneumonia and enteric disease are by no means confined to or characteristic of only one disease, as, for example the disease termed haemorrhagic septicaemia. Similar manifestations feature a number of other diseases, and their observance in respect to disease diagnosis needs to be interpreted with caution and reserve, especially when considering haemorrhagic septicaemia as a disease entity in itself and not as a complication or an end-stage of another disease.

It must be remembered that micro-organisms of the pastuerella or haemorrhiagc septicaemia group are frequently found in healthy swine as harmless inhabitants; also, that they are or may be concomitant with other infectious and specific diseases, and that in the end-stages of these diseases they may rapidly multiply, invade the tissues and hasten death. The finding of these organisms in the blood and body tissues after death is of limited significance and affords no proof of their having originated or taken a leading part in the disease which had occurred.

Years ago haemorrhagic septicaemia or swine plague and hog cholera or swine fever were regarded as one and the same disease caused by the same organism, *P. suisepticus*. The discovery of the virus of hog cholera shattered that conception and all authorities are now in agreement that the septicaemia so frequently encountered in hog cholera is a secondary

complication to that disease. In 1934, we ourselves investigated an acute disease of hogs which had been reported as haemorrhagic septicaemia. Five outbreaks were studied and each one proved to be hog cholera, three of them in association with septicaemia *(P. suisepticus)* and one with enteritis *(B. suipestifer).* These studies are given in detail by Dr. C. A. Mitchell in the Annual Report of the Veterinary Director General, March 31, 1935.

Granting the possible existence of haemorrhagic septicaemia as an independent disease, its occurrence as such is probably a rare thing, while its development as a secondary complication or follower of other diseases is comparatively frequent. When the diseases and factors on which this development so largely depends receive proper recognition it may safely be assumed that attention will revert and be focussed upon the primary, essential diseases and their causes instead of secondary invaders and contributors, and that haemorrhagic septicaemia will, in consequence, fall to a very much lower place in the rank of swine diseases.

Diseases of Nutrition

A great deal of the underdevelopment, poor physical condition, ill health and disease, especially in young pigs, can be attributed to faulty nutrition and parasitic infestation, one or the other or both together. Anaemia of young pigs is distinctly a nutritional disease apparently increasing in prevalence throughout the country. It means blood poverty. In this condition the blood corpuscles may be reduced to one-third, one-half or even one-quarter or less of their normal number and at the same time are deficient in mineral constituents, particularly iron compounds. This is due to inability of the blood forming tissues to produce normal blood as a result of malnutrition and deprivation of essential food elements. It leads to stunted growth and unthriftiness, loss of vitality and disease resistance, prepares a seeding ground for infection and, if severe and unchecked, causes high mortality.

Rickets is an example of one of the skeletal diseases associated with calcium and phosphorus deficiency; and goitre with an iodine deficiency. Certain forms of arthritis, crippling, and paralysis are connected with nutritional defects of one kind or another.

Parasitic diseases of swine have an important place in the picture under review and of these we need only name the more conspicuous: round worm infestation, coccidiosis, and sarcoptic mange.

There may thus be seen in this picture four principal groups of diseases which may be briefly stated as: 1, A group comprised of highly specific, infectious, independent diseases; 2, A group of more or less secondary infectious diseases, dependent upon various provocative factors; 3, Nutritional disease; and 4, Parasitic diseases. Those of the first group are constantly associated with their respective micro-organisms and viruses which, when they come in contact with and are taken into the system of a susceptible host, act directly. They may attack indiscriminately any or all animals of a susceptible species, with little regard for breed, age, sex, constitution, heredity, and environment. When the disease outbreak has spent itself or has been eradicated by drastic means the premises, after a thorough cleaning and disinfection and a short time interval, may be

restocked with little danger of a recurrence of the disease from within. A good example is hog cholera.

The second group, includes the diseases caused by infective agents which, year in and year out, are more or less present in the soil, in and about the pens, the buildings and environment. These micro-organisms continue for the most part a harmless existence even when harboured, carried and excreted by the animals themselves, but lie in wait, as it were, for conditions and opportunities which favour their multiplication and development, increase the susceptibility of animals liable to attack and indirectly promote disease. Their activation and the appearance or recurrence of the diseases in which they play their part depend upon local conditions and environment, exposure to sudden or severe climatic changes, improper housing, crowding, lack of sanitation, poor feeding, and deprivation of essential food constituents, malnutrition, constitutional weakness, the stress and fatigue of railway transportation and other factors which in various forms and combinations tend to lower health, vitality and normal disease resistance and provoke infectious processes.

The third group of diseases, the nutritional, depend only upon nutritional and physiological factors for their primary development and clinical manifestations, but frequently become linked up with diseases in the other groups. The relationship between malnutrition and infection is a delicate one, variable, and very difficult to define. Malnutrition may not directly result in infection but it may often be the deciding factor in respect to the course the infection may take—mild or severe.

Questions and Conclusions

In the foregoing conception of prevailing swine diseases in Western Canada and their causes, what is there of outstanding significance? And what are the actual problems?

Hog cholera is well taken care of and has ceased to be a major problem. There is, undoubtedly, the problem of swine tuberculosis, which depends largely upon tuberculosis in poultry. Then there is arthritis. The situation in respect to swine erysipelas is not clear and requires watching. Infectious abortion has not yet and, let us hope, will not come into the picture. But for the rest, which account for the bulk of unthriftiness, losses in sucking pigs and the general mortality on the farm, the problem can, I think, be clearly indicated and expressed in two words: Bad Management—bad husbandry! on the part of the man on the farm.

Throughout this Western country, and in the East as well, on the majority of hog raising farms, swine breeding, farrowing, care of the new born, feeding, housing, and all that pertains to good swine husbandry, appears to be carried on for the most part in a very haphazard way and with an unconsciousness of basic health requirements but an over-consciousness of disease.

How far does there come into the range of vision and practice of the average swine husbandmen the selection of breeding stock for constitutional fitness, for disease resistance, the special care required for the pregnant or farrowing sow and her large litter of sucklings; housing with an eye to construction, comfort, ventilation, sunlight, cleanliness, and sanitary needs;

feeding with a knowledge of nutritional values and requirements; clean, uncontaminated drinking water, suitable exercise pens, avoidance of overcrowding; and the ploughing and rotation of hog lots, etc. Is it surprising that when young hogs are weaned from their mothers' milk and fed on an exclusive diet of coarse grain, such as oats with a high content of fibre and hulls, and this apparently is being done very commonly, there follows a more or less severe intestinal irritation, indigestion, and state of malnutrition? Can it be expected that young feeder pigs will not suffer when they are subjected to a sudden change of diet from grain to garbage, and this again is a not uncommon practice? Is the average swine husbandman not more concerned with the administration of medicinal pills, condition powders, and disease remedies, the fetishism of a hypodermic syringe and needle and with what he thinks are short cuts to health, than with sound health principles and their intelligent practice? There are no short cuts to health, and there are no synthetic substitutes for health. There is an increasing and alarming tendency to trust to serums, vaccines, and preventive inoculations to overcome disease. For many of these widely used biological products and preparations there is little or no evidence of their value and efficacy, either protective or curative. Forgetful of the fact that many diseases are self-limiting, have run their course and have done all the damage they are capable of doing at the time a serum or vaccine is administered, the inoculations are often credited with results in which they have taken no part and to which they have no claim. Preventive inoculation and immunization have a place and a very valuable one in certain diseases, especially in what may be termed the acute, independent, contagious disease. Even so, it may be pointed out that no means of conferring immunity to a disease has ever resulted, in practice, in the eradication of that disease. Vaccination against hog cholera is fairly successful but in countries where it is practised, the infection is perpetuated, and in them it is hardly safe to attempt to raise pigs without vaccination; and so it is with many other animal and human diseases.

Nature never intended short cuts to health and does not tolerate them; when her biological laws and needs are neglected or defied she exacts a heavy penalty. Provocative disease may be and undoubtedly is one of Nature's means of getting rid of the weaklings, the constitutionally unfit, the impoverished and the unthrifty. In both human and animal races there develop sooner or later physically unfit members. Left to herself, Nature would suppress these and when they become so numerous as to endanger the race or species she employs very drastic means of eliminating them; and in achieving her end she does not hesitate to sacrifice many of the fit and efficient individuals. Everywhere there are germs lurking in the soil and in the animal body itself, living, for the most part, a harmless existence but subject, nevertheless, to call and provocation into disease activities. And these provocations, it may be stressed again, arise mainly from faulty living, breeding, feeding, and environmental conditions.

Swine are raised only for their commercial value. There is no profit in propagating the unfit or in raising animals in such a manner as to invite disease. Nature's drastic methods may be forestalled or not called into operation according to the attention paid to health laws and needs. It is true that the swine raiser may be so situated that he cannot afford the

cost of providing the necessary health requirements and equipment and at the same time make a profit when his hogs go to market. If this is so, then it is really too bad for the hog; and he is the victim of the conflict between the cost of his keep and health and the price of pork and bacon.

The laboratory services and specialist workers can aid and supplement the efforts of the man on the farm and in the field, but cannot substitute for him. The problem has to be solved in the field, not in the laboratory. From an angle of health—my theme is health, not disease, for health is a more important factor than disease—it is better and cheaper to start at the very beginning on a basis of health and build for health than to raise weaklings and then try every kind of substitute to keep them from falling down.

That there are swine disease problems is freely recognized. The independent, directly-acting diseases are relatively few and can be seen with fair clearness, and means for their control and eradication are not lacking. The dependent diseases are many and present a very confused picture. The view is obscured and the way of scientific approach obstructed by the many causes and conditions, varying in kind and degree, already pointed out and repeatedly stressed. For the most part, these can be and must be removed or corrected by the swine husbandman himself and no other. The problems will then be made clear and many of them without a doubt, will disappear. What is left will be exposed in distinct outline and significance and the way opened for scientific workers to make their attack and offer effectual aid, co-operation and contribution.

THE RELATIVE VITAMIN A CONTENT OF THREE VARIETIES OF NORTH WESTERN DENT CORN—MANITOBA-GROWN RED, YELLOW AND AMERICAN YELLOW

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Corn has been recognized for many years as a very popular grain in poultry rations whether feeding for growth, egg production, or for fattening. According to Fraps (2) corn is readily digested and is also very palatable. A number of investigators have shown that yellow corn has higher feeding value than white corn because it contains liberal amounts of the growth-promoting vitamin A. "Kempster (6) found that a ration containing 56% of yellow corn was superior to a similar ration containing the same proportion of white corn," when fed to laying hens. Kempster and Henderson (7), the Indiana Experiment Station (5) and the Poultry Husbandry Department of the University of Manitoba (8) have conducted experiments demonstrating the superiority of yellow corn over white corn in rations for growing chicks. Recent vitamin A studies by Herner (4) clearly demonstrated the vitamin A deficiency in white corn when fed to chicks. Lack of growth, sore eyes or xerophthalmia, and large amounts of urates in the kidneys and ureters were symptomatic of this deficiency.

Yellow corn also contains xanthophyll and carotene, both of which may be associated with vitamin A. These produce a rich yellow colour in the skin and shanks of yellow-legged chicks; a rich yellow color in the yolk of eggs; and a yellow fleshed carcass in market birds. However, it is largely for its growth promoting vitamin A content and its value in preventing disease or establishing resistance to it that yellow corn is preferred to white.

The use of corn has been more extensive in the warmer southern latitudes and in milder climates where it is easily grown than in the colder northern latitudes with their short growing seasons, dangers of frost and difficulty in getting maturity. The use of corn in these colder areas is also further restricted on account of transportation and importation costs, making it too expensive for economic poultry feeding. Nevertheless, restricted though the use of corn may be, many manufacturers and distributors of poultry feeds in the colder climates desire to have a certain amount of corn in their feed mixtures because of its high feeding value. However, the addition of imported corn generally raises the cost of poultry rations considerably, and an effort is being made, therefore, to encourage the use of corn grown locally rather than the imported product, in order to hold down the cost of mash and grain mixtures which poultrymen are using.

In the Prairie Provinces of Western Canada, the growing of corn has been confined very largely to the southern districts because of the longer growing period and the lesser frost hazard than farther north. While the amount grown and available for feeding purposes is rather limited, yet with the improvement of varieties and the shortening of the period of

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maturity the amount grown has increased, and if there is a good market it will still further increase from year to year. Since the amount grown locally has always been rather limited the imported corn has formed the chief source of supply, and on a competitive basis preference has been given to the imported product. To a certain extent, this has been due to the lower moisture content of imported corn and the lower risk in storing and handling it. Drying will, of course, eliminate this objection. In addition, the vitamin A content of the locally grown corn has heretofore been an unknown quantity, and until assurance can be given as to its relative growth promoting properties it may have to continue taking second place to the imported corn.

EXPERIMENTAL METHODS

In order to establish a definite rating as to the growth promoting value or the vitamin A content of Manitoba grown corn the Poultry Husbandry Department of the University of Manitoba undertook a special 8-week feeding experiment in January, 1937. The test was confined to two varieties of corn grown in Manitoba, viz., a red variety of Northwestern Dent and a yellow variety of Dent known as Falconer, and a sample of yellow commercial feed corn of the Northwestern Dent variety imported from the United States.

TABLE 1.—FORMULAE OF RATIONS AND PROTEIN CONTENT

Lot No.	1	2	3	4	5	6	7	8	9
	lbs. or %	lbs. or %	lbs. or %	lbs. or %	lbs. or %	lbs. or %	lbs. or %	lbs. or %	lbs. or %
American Yellow Corn, ground fine	60	40	20	–	–	–	–	–	–
Manitoba Yellow ground fine	–	–	–	60	40	20	–	–	–
Manitoba Red ground fine	–	–	–	–	–	–	60	40	20
White Corn, ground fine	–	20	40	–	20	40	–	20	40
Oat Middlings	21	21	21	21	21	21	21	21	21
Skim-milk Powder	10	10	10	10	10	10	10	10	10
Meat Meal (60% protein)	6	6	6	6	6	6	6	6	6
Lime Grit	1	1	1	1	1	1	1	1	1
Charcoal	1	1	1	1	1	1	1	1	1
Salt	1	1	1	1	1	1	1	1	1
Total	100	100	100	100	100	100	100	100	100
Protein Content	17.35	17.05	17.68	17.71	17.64	17.71	16.20	16.64	17.08

The feed formula was drawn up as shown in Table 1 with the basal ration as indicated and white and yellow corn interchanged in order to keep the total amount of corn in each ration constant or at the same level. With the basal ration completely void of vitamin A and with yellow corn as the only source of this vitamin, feeding it at the three levels provided an opportunity to study the effect of adding larger amounts and also to make comparisons as to the growth promoting value of each of the three varieties at three different levels. It will be noted in Table 1 that the protein level of all diets was slightly below that required for normal growth of chicks as given by Card, Kirkpatrick (1). The object of this was to have the chicks slightly more responsive to the growth promoting factors,

apart from that of protein, and thus be able to measure the effect of vitamin A, as a factor, more accurately. According to these figures, the protein content of the ration containing the particular sample of red corn fed to lots 7, 8 and 9 was considerably lower than that of the other two samples.

In regard to vitamin D, ample provision was made for this by giving each lot 20 minutes daily irradiation under the mercury quartz lamp.

No control lot was used because earlier studies furnished abundant evidence of a complete lack of vitamin A in a diet composed of 78% of white corn with the other ingredients and the protein and mineral supplements almost identical to those used in this experiment both as to nature and amounts.

On January 15, 1937, 270 newly hatched S.C. White Leghorn chicks were leg banded, weighed individually and divided into 9 lots of 30 each. An attempt was made to equalize the mean weights of all lots. These chicks were brooded in battery brooders under as uniform conditions as possible. The ration fed to each lot is indicated in Table 1. They were given water to drink *ad lib.* A sufficient amount of mash for each lot was mixed at the start to carry the chicks up to 8 weeks of age and an ample supply was kept before them continuously.

All the chicks were weighed individually each week and these weights recorded, as well as the amount of food consumed each week.

Some difficulty was experienced with cannibalism, and as a result the later mortality in a few of the lots is higher than it should be.

DISCUSSION

This experiment was designed primarily for the purpose of making comparisons as to the vitamin A content of three varieties of corn with the growth promoting factors as the chief index and deficiency disease symptoms as secondary factors. Besides providing a wider range for comparison the thought was that with yellow corn as the source of the vitamin and feeding it at 20, 40 and 60% levels, respectively, might also provide information as to what quantity would furnish the required amount of vitamin A in an otherwise A free ration.

A review of the data on average weights as presented in Table 2 shows a marked similarity in growth in all lots. The trend, however, seems to be towards accelerated growth when more corn is added. The

TABLE 2.—MEAN LIVE WEIGHT AT 8 WEEKS AND THEIR STANDARD ERROR

Lot No.	Males	Females	Males and females (weighted mean)
I	412.50 ± 20.34	344.68 ± 16.09	378.59 ± 12.97
II	382.08 ± 18.36	370.35 ± 17.20	376.22 ± 12.66
III	361.00 ± 20.34	349.00 ± 16.61	355.00 ± 13.14
IV	386.36 ± 19.40	357.50 ± 20.34	371.93 ± 14.06
V	400.64 ± 17.20	379.81 ± 19.40	390.23 ± 12.97
VI	414.33 ± 26.27	346.05 ± 15.61	380.19 ± 15.28
VII	416.58 ± 18.36	360.90 ± 20.34	388.74 ± 13.78
VIII	400.28 ± 24.33	348.37 ± 16.09	374.33 ± 14.58
IX	392.00 ± 20.34	335.31 ± 16.09	363.65 ± 12.97

exception to this is lot 4, and the reason would seem to be a severe outbreak of cannibalism which started the third week and raged till the fifth week, taking a death toll of 6 chicks in this period and also adversely affecting the growth of the survivors. Lot 7 passed through a similar experience, and while the mortality was high, preventive measures stopped it almost immediately and the effect on the survivors was not so disastrous. Cannibalism also caused some mortality in lot 6, but was brought under control very quickly. There was no evidence whatever of any pathological condition due to vitamin A deficiency.

In view of the fact that males grow faster than females and since the proportion varies in each lot, it is necessary to make adjustments as to the influence of sex on these weights. Furthermore, since diets differ as to variety of corn and also as to rate of feeding, it becomes necessary to make further analyses for variances as to these two factors.

A statistical analysis has, therefore, been made covering all these factors. In Table 2 are presented the mean live weights of the chicks at 8 weeks of age and their standard error. While there is considerable variation in these weights, yet the analyses presented in Table 3 and 4 would indicate that when the effect of both diet and sex are considered, there is no significant difference between lots. In making these analyses the method outlined and presented by Titus and Hammond (8) was followed.

TABLE 3.—PRIMARY ANALYSIS OF LIVE WEIGHTS

Source of variation	d/f	Sums of squares	Variances (mean squares)	Standard deviations
Sub classes	18	142.388	7,910.44	88.91
Error	199	824.373	4,142.57	64.36
Total	217	966.761	–	–

TABLE 4.—FURTHER ANALYSES OF LIVE WEIGHTS: THE EFFECT OF DIET AND SEX

Source of variation	d/f	Sum of squares	Variances (or mean squares)	Standard deviations
Diet	8	23,631.88	2,953.98	54.35
Sex	1	86,582.37	86,582.37	294.25
Interaction (sex and diet)	8	24,803.88	3,100.48	55.68
Error	199	824,373.00	4,142.57	64.36

Since there appear to be differences in the effectiveness of different rates of feeding the Manitoba Red and American Yellow, still further analyses were made by applying the Yates (10) method of fitting constants. This method was used to test the significance of difference between the rates of feeding. The results of these analyses are presented in Table 5, and obviously show that there are no significant differences between the rates of feeding these three varieties of corn.

Table 5.—Analyses of variances for rates of feeding within varieties

——	*DF*	*SS*	*MS*	*F*
Manitoba Red— Between Rates	2	6,034.30	3,017.15	.7283
Manitoba Yellow— Between Rates	2	4,526.98	2,263.49	.5464
American Yellow— Between Rates	2	7,501.32	3,750.66	.9054
Error	199	824,366.70	4,142.55	

These methods of variance analysis, therefore, indicate that there is no significant difference in the mean weights, at the conclusion of the experiment, when sex, variety of corn and rate of feeding it are considered.

However, these analyses show what appear to be trends that the vitamin A content of the 20% American corn in the ration fed to lot 3 is probably lower than that of all the other rations and definitely lower than that of the rations fed to lots 2, 5, 6 and 7. It would also seem that 20% of the Manitoba yellow and Manitoba red, fed in the other two rations provided sufficient vitamin A to bring the rate of growth up equal to the 40 and 60% levels of these varieties. These investigations, therefore, indicate that 20% of the Manitoba-grown corns provided sufficient vitamin A and suggest the possibility of 20% American yellow corn not being quite adequate for these requirements. Hauge, Carrick and Prange (3) reported that 25% of American yellow corn in the ration appeared to meet the vitamin A requirements of growing chicks up to 10 weeks of age.

Whatever variations and trends there are in the average weights of these chicks at 8 weeks of age cannot be attributed to the protein content of the ration because earlier protein studies established, first, that the protein requirements of a normal growth are higher than that contained in these rations, and, second, that small differences like these in protein content do not influence the rate of growth one way or the other. With the genetic make-up the same in all the chicks, and all other factors the same, it would

Table 6.—Mortality record

Lot No.	Number of chicks				Mortality		
	At start	At finish			1st week	Later	Total
		Males	Females	Total			
1	30	10	16	26	3	1	4
2	30	12	14	26	3	1	4
3	30	10	15	25	5	–	5
4	30	11	10	21	3	6	9
5	30	14	11	25	4	1	5
6	30	6	17	23	3	4	7
7	30	12	10	22	2	6	8
8	30	7	16	23	5	2	7
9	30	10	16	26	3	1	4

seem that apart from lot 4 the variations or trends can be attributed only to the vitamin A content.

In respect to yellow pigmentation in the skin and legs of the chicks there was no noticeable difference in any of the lots at 8 weeks, either as to amount or density.

CONCLUSIONS

The evidence shows: (1) that both Manitoba Yellow and Manitoba Red corn are fully equal to American Yellow in vitamin A content; (2) that 20% of either of these two varieties provided sufficient vitamin A in these rations to promote healthy growth; (3) that the addition of more corn of these two varieties did not produce any acceleration of growth. It might be added that there is a suggestion that 20% of American Yellow corn did not furnish quite as much vitamin A as the same amount of each of the Manitoba varieties, and a slight indication that this amount of American Yellow corn did not meet the vitamin A requirements of growing chicks up to 8 weeks of age.

The data on the protein content of these rations suggests the possibility of the Manitoba Red variety being lower in protein than the other three varieties in all three rates of feeding.

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THE PROBLEM OF DETERMINING THE DIETARY CALCIUM AND PHOSPHORUS REQUIREMENTS OF ANIMALS[1]

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In spite of the increasing attention to and realization of the importance of minerals in the nutrition of farm stock, and the rather voluminous literature already available on the subject, there is still very little accurate quantitative data regarding the requirements of animals for the two mineral elements needed in largest amounts, calcium and phosphorus. The levels of these two elements recommended for the rations of the various classes of stock under various conditions of production are actually based on data much less satisfactory than that on which our "feeding standards" for the primary organic dietary constituents have been calculated. In fact, one has only to discuss the question of minerals with feeders and even with some to whom feeders look for advice, to realize how unsatisfactory is the general understanding of the fate in the animal body of dietary calcium and phosphorus; of the principle roles which they play in nutrition; the effects or results of their deficiency; and the gross symptoms which such deficiencies show. It is, perhaps, in part, a result of this that many extravagant claims for the benefits of mineral feeding have so long been unchallenged, and the sale of expensive mineral mixtures flourished so extensively during the past few years.

Admittedly, there is much yet to learn about the problem of mineral nutrition, but on the other hand there is enough known already to answer many of the simple questions on the subject, and it may be worth while to summarize briefly a few of the main facts of calcium and phosphorus metabolism as a means of better appreciating the difficulties of research on this subject and also to give some basis for interpreting the results of such studies.

One of the first essentials in any study of animal requirements is a satisfactory measure or criterion of adequacy. The energy which must be supplied an animal for maintenance can be determined by a measurement of the heat lost from the body under certain defined conditions. The corresponding criterion of protein sufficiency is the loss of endogenous nitrogen from the body. Procedures for such determinations, though exacting, are well understood and reasonably straight forward. Production demands in excess of maintenance are indicated more or less directly by the body weight increases or productions made. Inasmuch as the end products of the metabolism of the organic nutrients are eliminated through paths different from that of undigested dietary residues or else are in such form as to be easily differentiated from them, a picture of their metabolism with reference to adequacy of ration intake can readily be obtained.

In the case of calcium and phosphorus, however, such criteria are for the most part quite unsuitable. They may even be misleading. For

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example, energy balances are useless, for these elements do not enter into the energy equilibrium of the body. Urinary excretion us but a minor fraction of the endogenous loss. These elements are excreted in the same form chemically as they were ingested, and hence endogenous, exogenous, and dietary residue fractions of the fecal excretions cannot be separated. Absorption from and re-excretion into the gut are in part governed by factors unrelated to dietary intake. The calcification and storage of these elements in the skeleton and their removal therefrom are processes proceeding more or less continually and also proceed in many cases quite independently of dietary intake. The quantity and ratio of calcium and phosphorus in the diet; the acidity of the intestinal tract; the presence of vitamin D; the activity of the endocrine system, especially the thyroid and parathyroids; and the individual status of the animal as to health, pregnancy, and milk or wool production are all factors influencing the metabolism of these two elements.

In the final analysis, the status of the mineral nutrition (calcium and phosphorus) depends on a balance between absorption from the diet, excretion from the body, and the rate of deposit in and withdrawal of these elements from the skeleton. Of these, the last named is by far the most important under normal conditions. After all, it is the condition of the "reservoir" that is important. Temporarily, it may be low with no harmful results to the animal. This, in fact, is the normal state of affairs at certain times such as early lactation, while at other times there will be rapid storage.

Since it is the status of the skeleton storage that is the final criterion of the adequacy of the calcium and phosphorus nutrition, the requirements for these elements must be determined with reference to the condition of this storage. Dietary intake is not a criterion, excepting that over long periods it may be too low. The blood picture is likewise unreliable unless followed long enough to smooth out the daily fluctuations in phosphorus content. In fact, the only accurate method involves the slaughter of animals carried on a known dietary regime and a direct determination of the condition of the mineral content of the bones. To date, some such tests have been carried out, but much more work is needed before anything comparable to "standard requirements" can be hoped for. "Slaughter" tests are slow and exceedingly expensive for the larger animals, and much evidence can be cited that there are marked species differences so that the work must be done on the particular species of animals to which the results are to be applied.

It hardly seems possible, therefore, at the present time to answer the oft raised question of how much calcium and phosphorus a diet should contain, beyond the very general findings from observation of the behavior of animals and a limited amount of experimental data which may be summarized tentatively as approaching, as minimums, the following percentages of the total dry matter of the ration:

	Calcium	*Phosphorus*
Cattle and sheep	0.40 to 0.20%	0.35 to 0.20%
Pigs	0.60 to 0.30%	0.45 to 0.25%
Poultry	0.75 to 0.40%	0.50 to 0.35%

In general, the requirements will decrease with age or maturity, and obviously may vary widely with local conditions and with individual animals.

Considering the character of feeds normally used for these classes of stock, it is quite generally accepted that the problem of supplemental mineral feeding in as far as it relates to dairy cattle usually concerns phosphorus, while with hogs and poultry it is calcium which must be supplied. The form in which they are fed is relatively immaterial,—most sources being equivalent per unit of the element contained.

THE BORON CONTENT OF APPLE TISSUES AS RELATED TO DROUGHT SPOT AND CORKY CORE[1]

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In conjunction with the work of McLarty (14, 15) and McLarty *et al.* (16) on the control of drought spot and corky core of apple in British Columbia, the boron content of the experimental plants was determined by chemical analysis. This paper summarizes the results obtained to date.

The position of boron as an essential element for plant growth has been well established by the works of Brenchley (5), Warington (19), Johnston (13), Haas (8), and many others. They have shown that boron is essential for normal growth and that its deficiency results in physiological disorders which are characteristic for the plant under experiment. In the apple it has been shown by McLarty (15) and Davis (10) in Canada, Atkinson (3) in New Zealand, and Jamalainen (11, 12) in Finland, that a disorder or disorders known variously as drought spot, corky core, cork, internal cork, brown heart, poverty pit, or crinkle are due to a deficiency of this element.

The quantitative determination of boron in plant tissues has been made by several investigators. Agulhon (1) found that the boron concentration in the stems and leaves of fir trees ranged from 7 to 14 p.p.m. while in the leaves of figs it was 79 p.p.m. Bertrand and De Waal (4) have reported on the comparative amount of boron found in 21 plants grown on the same soil. On a dry weight basis this ranged from 12 p.p.m. for barley to 571 p.p.m. for poppy. In a recent publication Eaton (7) reported that, in 127 samples of citrus and walnut leaves collected from various sources in California, the boron content varied from 35 to 1522 p.p.m. He showed further that its concentration varied widely in different organs of the same plant and even in the different parts of an individual organ such as the leaf. Piper (17) in Australia found that the boron content of normal apple fruit ranged from 12 to 30 p.p.m.

The comparative amounts of boron in plants affected with, and free from, deficiency symptoms has not been extensively determined. With internal cork or corky pit of apple Askew (2) found that the boron content of fruit from severely affected trees was 3 p.p.m. whereas that from the healthy was 12 p.p.m. The comparison in the leaves was 9 p.p.m. and 18 p.p.m. respectively. With brown heart of turnip, Hill and Grant (9) found that the diseased tubers contained 0.005% and the healthy 0.035% boron as B_2O_3 in the ash.

ANALYTICAL PROCEDURE

Sampling of Material

Most of the samples were collected from the 23-acre orchard which is being used as an experimental block in the study of these diseases. In addition, samples from other orchards both in British Columbia and

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Eastern Canada were included. Samples were taken of both tree tissues and of the soil in which the trees were grown. The parts of the tree used were: one year old twigs, mature leaves, and mature fruit. The twigs and soil samples were collected during the dormant period.

The twigs were cut into one inch lengths and dried at 75° C. to constant weight. The leaves were similarly dried. The fruit was cut into small slices and received a preliminary drying at 35° C. for approximately two weeks, after which the pieces were dried to constant weight at 75° C. The dried materials were ground, replaced in the oven at 75° C. for a further period of 24 hours and then cooled in a desiccator over calcium chloride. From each sample thus prepared two portions of approximately 30 gm. weight were taken and the analyses were made in duplicate. Each portion was weighed exactly and on this weight all calculations for the amount of boron present were based.

In securing the soil samples cores were taken with a 2-inch auger from 4 positions, each approximately 6 feet from the tree whose soil was to be tested. These cores were taken to depths varying from 12 to 24 inches. They were thoroughly mixed together and from the mixture a convenient sized sample (approximately one pound) was used. Each sample was air dried at room temperature and its moisture holding capacity was determined by the settling volume method (20). From the air dried sample an amount of soil was weighed which would hold 60 gm. of water at moisture holding capacity. It was on this weight of soil that the final calculations for the amount of boron present were based. The sample was shaken with 1500 ml. of distilled water and the mixture saturated with carbon dioxide by bubbling a rapid stream through it for 15 minutes. During this period the mixture was occasionally shaken. It was then allowed to stand in a closed container over-night. From this a clear soil extract was secured by drawing off the super-natant solution through a Livingston atmometer. A 1-litre aliquot was taken and evaporated to a convenient volume. This concentrated solution was then analyzed by the same method as used for the plant tissues after these had been ignited and taken up with water.

Method of Analyses

Several methods of analyzing for boron were tested. These include those developed by Bertrand and Agulhon (23), Brown (6), Smith (18), and Wilcox (21, 22). The method finally adopted was similar in almost all respects to that described by Wilcox. The method used was as follows.

The dried portion of the sample was removed from the desiccator and weighed, as noted above. It was thoroughly mixed with 5 gm. of finely powdered lime and ashed in a nickel crucible at dull red heat (400° to 450° C.) for 24 hours. The ash was transferred to a beaker and neutralized with concentrated hydrochloric acid. A slight excess (1 to 2 ml.) was added and the solution evaporated almost to dryness on a water bath. The partially dried residue was rinsed with methanol into a 350 ml. Erlenmeyer flask (hereafter referred to as the decomposition flask) and the volume made up to 50 ml. with additional methanol. To insure acid and anhydrous conditions in the solution during the subsequent distillation 1 ml. of concentrated hydrochloric acid and 10 gm. of anhydrous calcium chloride were added. The decomposition flask was then connected on one

side to a condenser and on the other to a reservoir which contained 250 ml. of methanol. The lead from the reservoir was carried well below the surface of the liquid in the decomposition flask. The reservoir and decomposition flask were placed on water baths. A receiving flask, containing 15 ml. of 0.5 *N* NaOH and to which was fitted a U-shaped trap containing 3 to 4 ml. of the same, was connected to the delivering end of the condenser. In operation, the rate of distillation of the alcohol from the reservoir was controlled so that no escape of methyl borate was possible through the system. When 250 ml. of distillate had collected in the receiving flask the distillation was deemed complete. The contents of the trap were rinsed into the receiving flask with distilled water. This solution was then made alkaline to phenolphthalein, if not already so, with 0.5 *N* sodium hydroxide, and an excess of 10 ml. of this reagent was added. Methanol was now distilled off and when only a few millilitres remained in the flask, the extract was transferred to a copper beaker, evaporated to dryness, and ignited at a red heat to destroy any organic matter. The residue was washed into a glass beaker, made acid by the addition of 6 *N* sulphuric acid, and boiled for 2 to 3 minutes in order to expel carbonic acid. When cool the solution was titrated.

The titration was by the electrometric method. The solution was brought to neutrality by the addition of dilute standard sodium hydroxide. After the reading on the burette containing the dilute standard alkali (0.02 *N*) had been taken, a gram of mannitol was dissolved in the sample and the standard sodium hydroxide again added until neutrality was reached. The amount of boron in the sample was determined by the amount of alkali required to neutralize the complex acid formed by the combination of the mannitol with the boric acid present in the solution.

Blanks were run through all stages of the procedure, and the necessary correction made in calculating the amount of boron in the sample.

A boron free glass (Kavalier) and copper beakers were used in order to avoid contamination from the slightly soluble boron trioxide present in many chemically resistant glasses.

Tests on the Method

1. *Titration Blanks for Soil Analysis*

Two hundred and fifty millilitres of distilled water were made slightly acid by adding a drop or two of 6 *N* sulphuric acid and boiling the solution to expel carbon dioxide. This solution was titrated by the complete electrometric method outlined above. For each lot of standard alkali used four such blanks were tested. The average of these results was used in making the necessary adjustment in all sample analysis. An example of such a titration blank was as follows: The amounts of alkali necessary to neutralize the solutions were found to be:

(1)	0.09 ml. of standard 0.024 *N* alkali.
(2)	0.11 ml. of standard 0.024 *N* alkali.
(3)	0.12 ml. of standard 0.024 *N* alkali.
(4)	0.10 ml. of standard 0.024 *N* alkali.
Average	0.10 ml. of standard 0.024 *N* alkali.

2. *Titration Blanks for Plant Material Analysis*

For each lot of reagents two complete check analyses were made. The average of these was used in making the necessary adjustments on sample analysis. During the course of this investigation impurities due to reagents varied from the equivalent of 0.30 to 0.70 ml. of 0.024 *N* alkali.

3. *Percentage of Recovery from Solutions of Known Boron Content*

Six complete analyses were made on a standard borate solution containing 0.96 mg. of boron per 10 millilitres. The recovery on these tests varied from 0.841 to 0.969 mg. of boron or an average recovery of 94.36%.

4. *Variations in Individual Samples*

Each sample was analyzed in duplicate, and data on the variations occurring in such analyses are presented in Table 1. These examples were chosen to give an indication of the accuracy to be expected at the different ranges of boron concentration.

TABLE 1.—RESULTS OF DUPLICATE DETERMINATIONS OF BORON IN SAMPLES TAKEN IN ROUTINE LABORATORY WORK

Sample No.	Portion A p.p.m.	Portion B p.p.m.	Difference p.p.m.
A18	211.0	215.0	4.0
L15	28.3	27.7	0.6
M11	19.1	22.1	2.0
M36	14.0	12.6	1.4
M36a*	13.0	13.6	0.6
D2	13.3	13.1	0.2
AFM12	12.2	12.8	0.6
M33	11.0	11.4	0.4
ATK38	7.4	7.2	0.2
ATQ1	6.0	6.0	0.0
A9	2.1	2.3	0.2

* Same as M36, but analyzed one year later.

RESULTS

Boron analyses of twigs from trees in the experimental orchard which were variously affected with drought spot and corky core are given in Table 2. In Table 3 are presented analyses of twigs, leaves, and soils from diseased trees in the experimental orchard which had received varying amounts of borax and boric acid, and from healthy trees in the laboratory orchard. A comparison is made in Table 4 of the boron contents of diseased and healthy apple tissues from various parts of Canada.

DISCUSSION

The results presented in the foregoing tables indicate a definite correlation between a low boron content in tree tissues and a high incidence of drought spot and corky core, and likewise a correlation between high boron content and absence of disease. Since the materials used in the analyses were taken almost entirely from British Columbia orchards, these correlations may be considered as being applicable only to this particular area. The analyses of materials secured from other fruit growing areas have not been sufficiently extensive to justify any conclusion that this relationship always maintains. In general, where no disease is present, the boron content of the twigs is at least 14 p.p.m. and where the diseases are severe, the boron content is below 10 p.p.m. Between 10 and 14 p.p.m. some disease may be expected.

TABLE 2.—THE RELATION OF THE BORON CONTENT OF TWIGS TO THE PERCENTAGE OF DROUGHT SPOT AND CORKY CORE

Tree No.	Variety	Drought spot	Corky core	Boron, p.p.m. dry weight
		%	%	
HH10	McIntosh	0	0	15.25
JJ12	McIntosh	0	0	14.59
AA25	McIntosh	0	0	14.17
JJ9	McIntosh	28	28	13.62
FF13	McIntosh	20	72	13.31
JJ24	McIntosh	33	–	12.51
LL9	McIntosh	80	48	11.46
BB23	McIntosh	0	0	11.45
CC25	McIntosh	0	0	11.44
DD12	McIntosh	84	52	10.57
HH18	McIntosh	24	20	10.21
X11	McIntosh	100	100	9.30
II17	McIntosh	100	92	8.69
KK21	McIntosh	92	68	7.97
GG16	McIntosh	64	44	7.61
W11	McIntosh	96	46	6.50
W10	McIntosh	100	90	6.49
EE16	McIntosh	100	90	6.31
GG26	McIntosh	20	20	6.22
HH26	McIntosh	100	100	6.11
GG25	McIntosh	80	100	5.71
EE23	McIntosh	56	100	5.63
EE17	McIntosh	100	100	4.89
KK27X	Wealthy	48	36	10.81
FF25X	Wealthy	30	90	9.95
II24X	Wealthy	72	96	8.90
JJ23X	Wealthy	92	96	8.44
HH25X	Wealthy	84	96	5.16
JJ27	Delicious	0	0	14.00
KK27	Delicious	0	0	13.75
HH29	Delicious	36	0	12.92
EE31	Delicious	10	0	12.64
II28	Delicious	0	0	11.22
FF29	Delicious	12	0	10.88
GG29	Delicious	20	0	10.38
EE8	Duchess	16	20	13.91
FF8	Duchess	64	96	11.61
II7	Duchess	100	100	9.49
LL5	Duchess	72	100	8.72
HH7	Duchess	100	100	8.44
KK6	Duchess	100	100	7.84
JJ8	Duchess	36	72	7.61

The results on soil analyses do not show as clear a correlation. Where the boron content of the soil was relatively high, such as was found in the plots receiving the applications of either boric acid or borax, the relation of these concentrations to reduction or abolition of the diseases was definite. Where the boron content of the soil was low as was found around all the check trees, some of which were healthy and some diseased, no correlation can be established. The reason why this should be, is not known. It is possible that the method used in making the soil extractions did not bring into solution all the boron available to the trees. On the other hand McLarty's observations (14) that diseased trees suffer from heavy rootlet

killing, may offer an explanation for this absence of correlation. It may be that trees on which rootlet injury has occurred have been weakened in their ability to absorb this element.

TABLE 3.—COMPARISON OF THE BORON PRESENT IN LEAVES AND TWIGS OF THE McINTOSH APPLE, AND SOILS FROM TREATED PLOTS

Tree No.	Treatment March, 1936	1935 DS*	1935 CC	1936 DS	1936 CC	Boron p.p.m. dry weight Leaves	Twigs	Soils
Departmental Orchard, Kelowna								
		%	%	%	%			
J18	¼ lb. Boric Acid	48	48	8	0	15.1	10.4	0.98
K17	½ lb. Boric Acid	76	64	0	0	21.6	11.8	0.55
L16	1 lb. Boric Acid	90	70	0	0	19.1	8.7	0.99
M15	2 lb. Boric Acid	82	38	0	0	19.5	11.4	1.69
N14	4 lb. Boric Acid	62	28	0	0	26.6	15.5	2.32
J17	¼ lb. Borax	68	48	10	0	15.0	12.0	0.59
K16	½ lb. Borax	48	8	0	0	13.3	9.5	0.46
L15	1 lb. Borax	00	00	0	0	28.0	13.8	0.49
M14	2 lb. Borax	84	32	0	0	20.1	12.8	0.92
N13	4 lb. Borax	56	28	0	0	23.6	21.8	1.53
J15	Check	56	00	8	18	10.2	6.0	—
M12	Check	9	9	78	21	14.1	6.0	—
K18	Check	96	84	8	4	—	—	0.13
L17	Check	100	60	0	0	—	—	0.12
M16	Check	68	40	12	12	—	—	0.18
N15	Check	88	24	0	0	—	—	0.19
Laboratory Orchard, Summerland								
1D	Check	0	0	0	0	—	14.5	0.08
2D	Check	0	0	0	0	—	14.5	0.08
3D	Check	0	0	0	0	—	15.0	0.05
4D	Check	0	0	0	0	—	11.3	0.07

* DS—Drought spot.
CC—Corky core.

SUMMARY

1. The boron content of apple tissues and the soils in which the trees were growing was studied with particular reference to the occurrence of the physiological disorders, drought spot and corky core.

2. It is shown that low boron concentrations in the tree tissues can be correlated with high incidence of disease. In twigs from trees where the diseases were severe the boron content was generally below 10 p.p.m. In twigs from healthy trees the boron content did not usually fall below 14 p.p.m.

3. A correlation between low concentrations of boron in the soil and incidence of the disease was not established.

4. High soil concentrations, induced by treatment with either boric acid or borax, were associated with a general freedom from these diseases.

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TABLE 4.—A COMPARISON OF THE BORON CONTENT OF DISEASED AND HEALTHY TWIGS, LEAVES, AND FRUITS OF THE McINTOSH APPLE FROM VARIOUS PARTS OF CANADA

Source	Condition	Boron, p.p.m., dry weight		
		Twigs	Leaves	Fruit
Kelowna—British Columbia	Healthy	14.1	18.2	—
		11.8	10.8	9.6
		14.1	17.7	27.6
	Injected*	14.9	23.2	20.9
		14.3	17.4	12.5
		14.4	13.5	22.0
	Diseased	6.4	5.4	2.2
		9.3	4.8	3.2
		9.3	6.8	4.5
Summerland—British Columbia	Healthy	14.5	—	13.4
		14.5	—	13.2
		15.0	—	13.1
Vancouver—British Columbia	Diseased	7.3	—	—
Picton—Ontario	Diseased	—	—	5.8
Macdonald College—Quebec	Healthy	8.7	20.9	5.2
		12.2	24.0	12.6
		10.8	24.7	11.0
Oka Orchard—Quebec	Diseased	6.1	16.1	2.7
		5.9	12.1	2.5
		6.2	14.1	2.1
Fredericton—New Brunswick	Healthy	10.3	17.8	5.0
	Diseased	11.5	12.5	4.7
Kentville—Nova Scotia	Healthy	9.3	13.5	—
	Diseased	7.3	9.3	6.5

* These trees had been injected with various amounts of boric acid in 1934. Samples for analysis were collected in 1935.

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